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ESSAYS ON M&AS AND INNOVATION

DISSERTATION

to obtain the degree of Doctor at Maastricht University,
on the authority of the Rector Magnificus Prof. Dr. Rianne M. Letschert, in accordance with the decision of the Board of Deans, to be defended in public on Friday 22 June 2018, at 09:30 hours in Maastricht

BY
MARTA FERNÁNDEZ DE ARROYABE ARRANZ

This thesis was written under the jointly supervised double degree program of the University of Luxembourg and Maastricht University

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CHAPTER 1

INTRODUCTION

Innovation has increasingly become an important way for firms to obtain and maintain a competitive advantage and to achieve a higher performance in the long run (Cassiman and Colombo, 2006; Conner, 1991; Hitt et al., 1997; Teece et al., 1997). Since firms' competitiveness depends on firms' ability to keep up with innovative products and processes, firms' research and development (R&D) activities, which stimulate innovation and improve firms' absorptive capacity, are key for improving firms' performance (Griffith et al, 2004; Levinthal, 1989; Pavitt, 1990). R&D activities lead to the creation of new technologies that can be used to develop new products that satisfy consumers' needs and market demand, or to develop new processes that lower the production costs, increasing market share, sales and profits (Pavitt, 1990).

While firms' main innovation input comes from internal R&D activities (Griliches, 1979; Scherer, 1982), the increasing complexity of research as well as the fast pace of technological change, impedes even the largest innovative firms to keep up with all the relevant technological advances by uniquely relying on their internal R&D (Cassiman and Veugelers, 2006; Rigby and Zook, 2002; Teece, 1988). Thus, on top of internal R&D activities, firms also make use of knowledge external to the firm through, for example, licensing, R&D outsourcing, M&As or hiring of scientific personnel (Arora and Gambardella, 1990; Cassiman and Veugelers, 2006; Cockburn and Henderson, 1998; Granstrand et al., 1992).

In particular, mergers and acquisitions (M&As) are a highly popular strategy not only to access new knowledge, capabilities and technology assets, but also as an important means of corporate development that permits firms' growth (e.g. expansion of customers' base and product diversification) and internationalization (Ahuja and Novelli, 2014; Cartwright and Schoenberg, 2006; Cassiman and Colombo, 2006; Teerikangas et al., 2011). In the US alone over 13,000 transactions were carried out in 2016, representing over $1.700 trillion in value (S&P Global Market Intelligence, 2017). As compared to previous M&As waves, since the 1990's the proportion of M&As pursued in technology-based industries has increased as well as the number of technologically-motivated acquisitions (Cassiman and Colombo, 2006; Martynova and Renneboog, 2008). This is because M&As are an important means by which firms can access technological assets and know-how held by the acquisition target (Arora, Fosfuri & Gambardella, 2001; Capron, Dussauge & Mitchell, 1998; Cassiman, Colombo, Garrone & Veugelers, 2005; Granstrand & Sjolander, 1990; Graebner, 2004). M&As grant access to technological competencies and capabilities (Chaudhuri and Tabrizi, 1999; Granstrand & Sjolander, 1990) and to essential intellectual property rights (Grimpe and Hussinger, 2008; 2014), therewith complementing or extending the technology portfolio of the acquiring firm (Ahuja and Katila, 2001; Cassiman et al., 2005; Cloodt, et al., 2006).

Nevertheless, despite the potential benefits M&As provide access to, a set of mixed innovation and performance results have been found. M&As studies report both positive and negative effects, but with a large body of literature documenting a negative impact of M&As on corporate innovation (e.g. Cassiman et al., 2005; Prichett, 1985; Ravenscraft and Scherer, 1987; see Veugelers, 2006, for a survey of the literature). This fragmentation in M&As' outcomes is also supported by acquiring managers who evaluate positively the success of the transaction (as compared to the original objectives) in only about half of the M&A transactions (Cartwright and Schoenberg, 2006; Schoenberg, 2006).

These fragmented findings suggest that M&As are still not very well understood and that scholars still know very little about what makes M&As succeed or fail (Bower, 2001; Hoskisson et al., 1991; Jemison and Sitkin, 1986; Schweizer, 2005). This lack of understanding should not come as a surprise, as there is only a limited number of studies that examine M&As from an innovation lens, in sharp contrast for example to the extensive literature on the financial and economic performance of M&As (Ahuja and Novelli, 2014; Veugelers, 2006). The studies on this dissertation aim at contributing to the M&As and innovation literature and focus on highlighting mechanisms by which innovation could be increased in the post-M&A period and on understanding why M&As take place in the first place, taking both a firm and policy perspectives.

Next section provides more details of the specific contributions of each of the chapters on this dissertation with a particular focus on the research questions underlying each of the studies.

1.1 RESEARCH QUESTIONS

This dissertation addresses the inter-relation between M&As and innovation, focusing on the antecedents and consequences of M&As from an innovation and policy perspective. In particular, it empirically examines the following research questions:

1. Does the hiring of external key inventors remedy inventors' innovation performance declines in the post-M&A period?
2. Do M&As represent a mechanism of knowledge diffusion through mobile inventors?
3. What is the impact of patent expiration on firms' acquisition decision and how does innovative capability moderate this effect?

Firstly, although M&As are acknowledged as an important means to access innovative assets and know-how, research has often reported innovation performance declines in the post-M&A period (see Veugelers, 2006, for a survey). Previous literature has pointed out to financial, managerial and organizational constraints related to an M&A event as reasons for the post-M&A declines (e.g. Chatterjee, 1986**;** Hitt et al., 1990; 1991; 1996). These changes in the aftermath of M&As have performance implications for the inventors within the firm, whose individual contributions add up to the firm's innovation performance. While individual talents are the sources of knowledge and innovation (Grant, 1996; Hoskisson, Hitt, Wan & Yiu, 1999), firms facilitate the exploitation of their knowledge by developing routines (Cyert & March, 1963; Nelson and Winter, 1982), which are disrupted in the post-M&A period creating uncertainty that generates demotivation and cognitive barriers to knowledge exploitation (Jensen & Szulanski, 2004; Minbaeva, Pedersen, Björkman, Fey & Park, 2003). Inventors react with departure or decreasing innovation performance (Ernst & Vitt, 2000; Kapoor & Lim, 2007; Paruchuri et al., 2006). Prior studies treat acquiring firms as passive observers that need to accept inventors' departure and innovation performance declines of incumbent inventors. The first empirical study in this dissertation adds to the prior literature by exploring a mechanism by which firms can counteract the post-M&A negative effects on innovation. In particular, this study makes use of the literature that illustrates the importance of the transferability of knowledge across and within firms through individual talents (Kim, 1997; Song et al., 2003; Zander and Kogut, 1995) to explore the potential role that key inventors play in knowledge transfer in periods of reorganization and that can mitigate negative innovation performance effects in post-M&A periods.

The second paper deviates from the other two by taking a policy perspective on the topic of M&As and innovation. Competition authorities carefully scrutinize and limit announced M&As because of the potential negative consequences in product markets as well as innovation in the industry (e.g. Ornaghi, 2008, Comanor and Scherer, 2013 and Szücs, 2014, Haucap and Stiebale, 2016). Regarding innovation, a dominant position in the product markets can reduce incentives to invest in research and development (R&D) for the merging parties due to reduced competition (Arrow, 1962; Reinganum, 1983) and for the competitors due to a reduced business stealing effect (Haucap and Stiebale, 2016). As explored on the first study of this dissertation, a major obstacle to realize innovation gains after M&As is the departure of the inventive labor force (Ernst and Vitt, 2000; Paruchuri et al., 2006; Kapoor and Lim, 2007). While previous literature only acknowledges the negative effects of inventors' departure in the merging firms' innovation, this study goes beyond to explore the potential positive effects derived from the post-M&A departure of inventors on third (non-M&A) parties. In particular, the paper empirically examines the patterns of mobility of inventors during the post-M&A period to determine whether and to which extent M&As represent a mechanism of knowledge diffusion through mobile inventors (Kogut and Zander, 1992; Schumpeter, 1934).

Finally, the third study moves from the analysis of consequences of acquisitions on innovation to the analysis of the innovation antecedents of acquisitions. Despite the importance of acquisitions as a strategy to access new knowledge and technology assets, the number of studies exploring the motivations behind firms' acquisition decisions (Andrade et al., 2001; Higgins and Rodriguez, 2006) is little as compared to the number of studies on the consequences of acquisitions on firms' performance (e.g. Ahuja and Katila, 2001; Cassiman et al., 2005; Cloodt et al., 2006; King et al., 2004). Previous literature has pointed out that adequate empirical research on acquisitions that deepens on the motives, industry sector and firm characteristics is necessary if researchers want to fully understand the performance outcomes of acquisitions and the high failure rates (Bower, 2001; Pablo and Javidan, 2004; Schweizer, 2005; Sirower, 1997). Framed in the resource-based view of the firm (RBV), the final paper of this dissertation aims at filling this gap by exploring an innovation mechanism that motivates pharmaceutical firms' decision to engage in M&As. In particular, this paper examines the impact that the expiration of patents, as a technological source of competitive advantage, has on firms' decision to engage in acquisition activities. From the innovation point of view, the loss of strategically key innovation resources pushes firms to undertake acquisitions to fill the gaps in firms' product pipelines left by the expiring patents (Comanor and Scherer, 2013; Danzon et al., 2007; Grabowski and Kyle, 2008; Higgins and Rodriguez, 2006; Rafols et al.,2014).

1.2 THESIS DATASET

The thesis dataset was constructed linking different sources: Thomson One Banker, Compustat, USPTO, NBER and the Coleman Fung Institute for Engineering Leadership.

Thomson One Banker provided (Thomson Reuters) was used to extract information about M&As deals. This dataset contained information of all M&A deals between US publicly listed firms for the period 11/1976 to 03/2013, which accounted for 36,841 observations. Many of these observations corresponded to the same deal; a deal could have multiple entries, each of which corresponding to different dates in which the acquiring firm bought stock from the target firm. After aggregating those, removing minority deals and deals occurring out if the window of interest (01/1980-12/2010), removing acquisition of assets (same target and acquiring firm), removing duplicated entries, and discarding deals with more than two parties and uncompleted deals, a total of 7,056 observations were left.

On a second step, I matched the data on M&A deals with Compustat. The match between the two databases is based on firms' name, state, and the firms' identifiers CUSIP and PERMNO (taken from the Center for Research in Security Prices (CRSP) database). For this, I independently matched target and acquiring firms. The 7,056 eligible deals contained 6,125 unique targets and 3,960 unique acquiring firms. At the end a total of 5,255 matches, i.e. financial information reported in Compustat, were found for the targets (from the non-matched 46% were firms in deposit banking or closely related functions, including fiduciary activities –sic code 60–), and 3,491 matches for the acquiring firms (from the non-matched 42% are located in finance and services –sic codes 60 to 90).

Finally, I used the USPTO, the NBER and Coleman Fung Institute for Engineering Leadership (Li et al., 2014)[1] to obtain information on the inventors and the patenting activity of the firms' involved in M&As. I successfully matched all the 6,125 unique targets and 3,960 unique acquiring firms to the NBER database. I found that 1,930 targets had innovation activity (as defined by at least one granted patent) and 1,577acquiring firms were active on innovation. Using the patent numbers from the NBER, I obtained data on the mobility of inventors from the Coleman Fung Institute for Engineering Leadership database. This database assigns an inventor ID to all individuals that are listed on USPTO patent documents. Based on this ID, inventors can be traced across different firms by their reappearance on patent documents. I use patent numbers to link inventors to different firms that appear as patent applicants on the patent documents and to track their mobility. Throughout the whole data linking process, manual checks were conducted, in particular for firms with missing or ill-defined linkages between the datasets due to misspellings of firm names or identifiers.

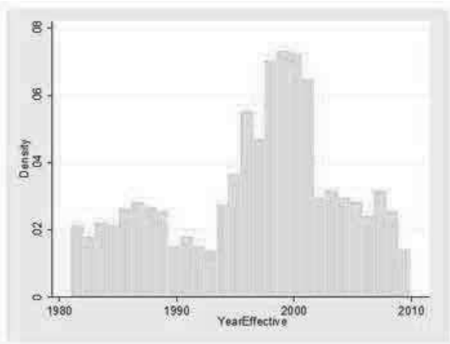
Below you can find a set of figures that depict the main characteristics of the database. Figure 1-1 (left) and Figure 1-1 (right) display the distribution of M&As deal by year and industry (as defined by the two-digit SIC code). The largest amount of M&As transactions occurred around the year 2000, with the electronics, industrial machinery, chemical and auto services representing the largest proportion of M&As.

[1] Formerly the Patent Network Dataverse from Harvard Institute for Quantitative Social Science.

Figure 1-2 (left) and Figure 1-2 (right) show that on average the acquiring firms included in this dataset had between 11 and 18 patent applications per year, while target firms only had an average of 1 to 3 patent applications per year (Figure 1-3 (right) and Figure 1-3 (left)). Moreover, acquiring firms had on average between 22 and 40 inventors (Figure 1-4 (right) and Figure 1-4 (left)).

Figure 1-1 (left). Number of M&A deals by year in which the deal took place.

Figure 1-1 (right). Number of M&A deals by industry (SIC two-digit classification).



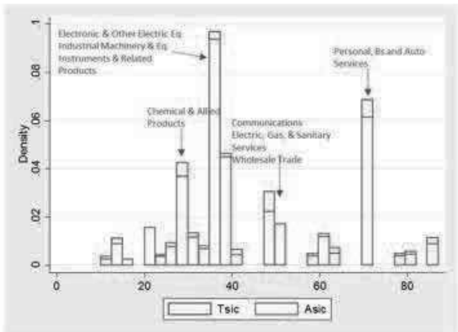


Figure 1-2 (left). Average number of patent applications per year (Acquiring firms).
Figure 1-2 (right). Average number of patent applications relative to the year of the M&A deal (Acquiring firms).

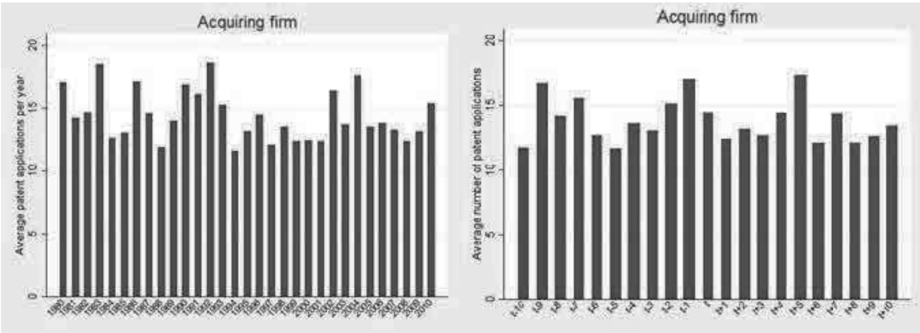


Figure 1-3 (left). Average number of patent applications per year (Target firms).
Figure 1-3 (right). Average number of patent applications relative to the year of the M&A deal (Target firms).

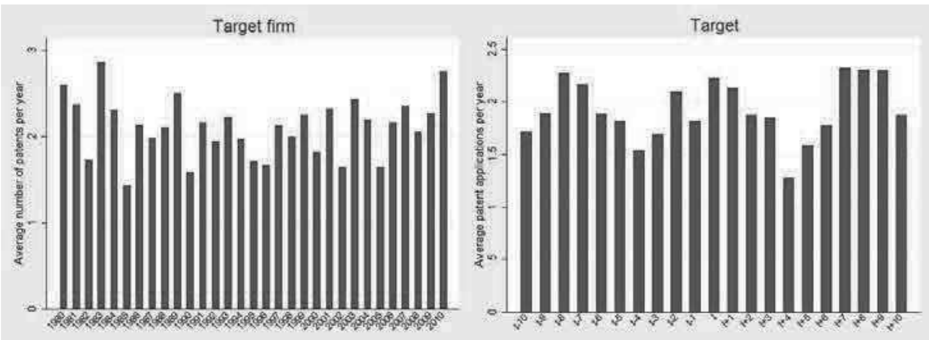
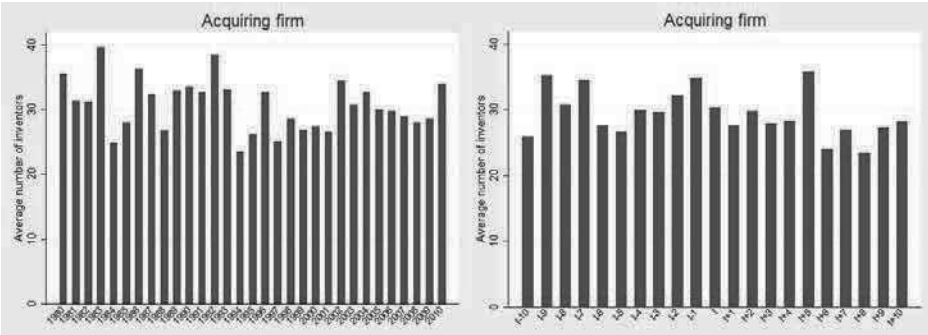


Figure 1-4 (left). Average number of inventors per year (Acquiring firms).

Figure 1-4 (right). Average number of inventors relative to the year of the M&A deal (Acquiring firms).



Based on this dataset, we obtain the different samples for each of the chapters. The sample from chapter 2 is based on the full database described here (a total of 1,402 deals). Chapter 3 considers only a subsample of the dataset as it focuses on those deals for which the acquiring firms have inventors that are active in the 5 years after the M&A, resulting in a total of 474 deals examined. Thus, for example, acquiring firms with no innovation activity or firms for which the inventors are not active after the M&A are not included in this chapter's sample. Finally, for Chapter 4, the sample is restricted to acquisitions in the pharmaceutical industry, which amounts to 85 deals.

1.3 OUTLINE

The core of this dissertation is composed of three empirical studies, presented in Chapters 2[2], 3[3] and 4, in which the research questions above

[2] Joint work with Katrin Hussinger (University of Luxembourg) and John Hagedoorn (UNU-Merit).

mentioned are explored. Each Chapter provides an introduction to the topic, reviews the relevant literature, presents the methodological set up for the empirical study, empirically tests the research questions, discussing the results, and lastly provides a conclusion in which managerial implications are also outlined. Each of these three chapters can be read independently from the others. Chapters 2 and 4 develop from the standpoint of the firm, while chapter 3 takes a policy perspective. Finally, Chapter 5 provides a review of the main findings, discusses the implications of this dissertation for both practitioners and scholars, and points out the limitations of the papers while also proposing new directions for future research.

[3] Joint work with Katrin Hussinger (University of Luxembourg).

CHAPTER 2

HIRING NEW KEY INVENTORS TO IMPROVE POST-M&A INNOVATION PERFORMANCE

2.1 INTRODUCTION

Mergers and acquisitions (M&As) are an important means by which firms can access technological assets and know-how held by the acquisition target (Arora et al., 2001; Capron, Dussauge and Mitchell, 1998; Cassiman et al., 2005; Granstrand and Sjolander, 1990; Graebner, 2004). M&As grant access to technological competencies and capabilities (Chaudhuri and Tabrizi, 1999; Granstrand and Sjolander, 1990) and to essential intellectual property rights (Grimpe and Hussinger, 2008; 2014), therewith complementing or extending the technology portfolio of the acquiring firm (Ahuja and Katila, 2001; Cassiman et al., 2005; Cloodt et al., 2006).

The expected benefits of M&As for innovation notwithstanding, most empirical studies report innovation performance declines in the post-M&A years (see Veugelers, 2006, for a survey) due to a shift of managerial attention from daily business activities and innovation to the M&A event

(Hitt et al., 1990), M&A-induced financial constraints (Hitt et al., 1996) or organizational and cultural differences between target and acquiring firm (Chatterjee, 1986; Hitt et al. , 1991). These changes in the aftermath of M&As have performance implications for the inventors within the firm, whose individual contributions add up to the firm's innovation performance. According to the individualist tradition of the knowledge-based view of the firm (KBV) (Felin and Hesterly, 2007), individual talents are the sources of knowledge and innovation (Grant, 1996; Hoskisson et al., 1999), while the role of firms is to facilitate the exploitation of their knowledge by developing routines which in turn define the context in which knowledge workers carry out their own routines (Cyert and March, 1963; Nelson and Winter, 1982). M&As and their organizational implications constitute a disruption of these routines which creates uncertainties regarding job security and task definitions and therewith induce demotivation and cognitive barriers to knowledge exploitation (Jensen and Szulanski, 2004; Minbaeva et al., 2003). Inventors react departing or decreasing innovation performance (Ernst and Vitt, 2000; Kapoor and Lim, 2007; Paruchuri et al., 2006).

Prior studies on the effects of M&As on innovation performance treat acquiring firms as passive observers that need to accept inventors' departure and innovation performance declines of incumbent inventors. We argue that acquiring firms can take measures to counteract innovation performance declines such as hiring new key inventors (Aggarwal and Hsu, 2012). Drawing from knowledge-based view (KBV), we argue that the hiring of new key inventors has two effects on post-M&A innovation performance. First, newly hired key inventors can constitute novel and superior sources of knowledge, strengthening the knowledge base of the acquiring firm. Hence, they are expected to have a direct positive effect on the innovation performance of the acquiring firm after the M&A. Second, we derive from KBV and the theory of organizational learning that there is an important indirect effect in the sense that these newly hired talents improve the innovation performance of incumbent inventors.

The contribution of our paper to the literature on M&As and innovation is twofold. First, we study the effect of M&As on the innovation performance of the acquiring firm through a KBV lens (Grant, 1996; Kogut and Zander, 1992; Simon, 1991). The KBV of the firm provides an alternative view to firm level explanations for the often observed innovation performance decline after M&As, employing the inventor as the major source of knowledge creation and innovation, treating the M&A as a disruption of the knowledge exploitation procedure (Paruchuri et al., 2006). We add to the prior literature on inventor behavior around M&As (Ernst and Vitt, 2000; Kapoor and Lim, 2007; Paruchuri et al., 2006) by disentangling different channels for the decline in post-M&A innovation performance. We distinguish between innovation performance declines due to inventor departure and innovation performance decreases of incumbent inventors that stay with the merged entity. We find that the effect on innovation performance of the inventors that stay within the firm is larger than the well-researched effect of inventor departure. This is an interesting finding given that prior literature pays a lot of attention to the consequences of inventor departure after M&As (Ernst and Vitt, 2000; Kapoor and Lim, 2007; Larsson and Finkelstein, 1999; Paruchuri et al., 2006). Our result is in line with organizational learning theories that emphasize the importance of the transactive memory of the firms (Argote and Ren, 2012; Wegner, 1987). The transactive memory defines the shared system that individuals in organizations develop to collectively encode, store, and retrieve information or knowledge in different domains (Wegner, 1987). Due to organizational changes and inventor departure during the M&A period, organizations' knowledge storage and exploitation system suffer, with severe implications for the innovation performance of the remaining inventors.

Second, from the KBV assumption that the inventor is the source of knowledge we derive that firms can take measures to counteract innovation performance declines in the post-M&A period. We demonstrate that the hiring of key inventors has important direct and indirect effects on post-M&A innovation performance where the latter effect refers to a positive effect of new key inventors on incumbent inventors' contribution to the firm's innovation performance. These results indicate that an appropriate human capital strategy around the M&A event can help avoiding a temporary decrease in innovation performance in the post-M&A period. Our findings have important practical implications for executives being involved in an M&A, suggesting a proactive human resource strategy, avoiding a brain drain and stimulating the hiring of external key inventors.

2.2 THEORY DEVELOPMENT & HYPOTHESES

2.2.1 Knowledge creation within the corporate context

The knowledge-based view of the firm recognizes knowledge as the most important strategic resource for the firm (Grant, 1996), pointing out the essential role of knowledge for value creation and for achieving a competitive advantage (Barney, 1991; Felin and Hesterly, 2007). Individuals are viewed as the sources of knowledge and talent, while the role of organizations is to facilitate knowledge exploitation (Cyert and March, 1983; Grant, 1996).[4] Firms present a platform that enables individuals to interact and to exchange knowledge (Grant, 1996).The process of knowledge exploitation is facilitated by the context the firm provides and its organizational routines within which knowledge workers carry out their tasks and develop their own routines (Cyert and March, 1963; Nelson and Winter, 1982). Routines provide guidance for individuals within an organization and facilitate coordination (Kapoor and Lim, 2007; Winter, 1986) through formal and informal procedures and communication (Szulanski, 2000). Even though routines can be simple sequences, they are able to support complex patterns of interactions between individuals (Grant, 1996) and to store knowledge and information (Darr et al., 1995), making them key in the knowledge production process (Levitt and March, 1988).

Firms' collective experience, generated as a by-product of firms' daily operations, interacts with the corporate context to create knowledge (Argote and Miron-Spektor, 2011). The information inherent in the firms' experience, routines, and corporate culture is stored in a common knowledge base which is also referred to as the firm's transactive memory which allows individuals to access the knowledge of each other and grants the opportunity to share, integrate and transform individual knowledge inputs (Argote and Miron-Spektor, 2011; Grant, 1996; Wegner, 1987).

The process of transforming knowledge, skills and talents of people into innovations is, however, complex. KBV argues that knowledge characteristics such as tacitness (Zander and Kogut, 1995), complexity

[4] Acknowledging that knowledge and creativity are embodied in talented people (Rao and Drazin, 2002), individual talents and human capital deserve adequate attention as key ingredients of the knowledge creation process (Kogut and Zander, 1992; Song et al., 2003; Zucker et al., 2002).

(Hansen, 1998), and causal ambiguity (Szulanski, 1996), as well as difficulties in establishing interpersonal interactions (Szulanski, 1996), impede the transformation of knowledge into innovation. This is why firms' experience, routines, corporate culture and transactive memory are important facilitators. M&As represent a sensitive disruption to these facilitators, inducing uncertainties and task-outcome ambiguity for inventors and other employees, impeding the process of knowledge integration and exploitation with implications for innovation (Ernst and Vitt, 2000; Kapoor and Lim, 2007; Ranft and Lord, 2000; 2002).

2.2.2 The impact of M&As on innovation performance

Prior studies have largely documented the negative impact of M&As on corporate innovation (e.g. Cassiman et al., 2005; Prichett, 1985; Ravenscraft and Scherer, 1987; see Veugelers, 2006, for a survey of the literature). This innovation decline can be traced back to several firm-level factors. First, managerial attention shifts away from daily activities and R&D to managing the M&A event (Hitt et al., 1990). Second, from a financial point of view, the pressure imposed by the acquisition investment (Hitt et al., 1991; Miller, 1990) and the introduction of cost-saving programs aimed at eliminating duplicative research efforts (Lengnick-Hall, 1991; Veugelers, 2006) may induce cutbacks of R&D budgets. Finally, insufficiently planned and poorly executed post-M&A integration has shown to hamper inventor innovation performance significantly (e.g. Haspeslagh and Jemison, 1991; Jemison and Sitkin, 1986; Pritchett, 1985). The negative effects are stronger in the presence of cultural and organizational differences between acquirer and target as well as low technological proximity (Ahuja and Katila, 2001; Cassiman et al., 2005; Cloodt et al., 2006; Ernst and Vitt, 2000).

These firm-level factors affect the performance of individual inventors by impeding inventors' and organizational routines. The post-M&A integration process typically implies strategic reconfigurations and restructuring activities (Karim and Mitchell, 2000), higher fluctuation rates of personnel and changes in job definitions and positions (Ernst and Vitt, 2000; Walsh, 1988) that may create a sense of dislocation and even trauma for the individual inventor (Cartwright and Cooper, 1993; Paruchuri et al., 2006). Inventors within the acquiring firm become concerned about the future strategic direction of the firm and the implications for their tasks, their employment safety, and the future definition of their position within the firm (Souder and Chakrabarti, 1984). Psychological reactions generated by the disruptive nature of the M&A event limit the cognitive ability of inventors and their capability to process new information (Fugate et al., 2008). Inventors' attention is focused on coping with the disruptive situation rather than processing work-related information (Fugate et al., 2008; Staw et al., 1981). This creates a cognitive barrier to the exploitation of the inventors' knowledge (Jensen and Szulanski, 2004; Minbaeva et al., 2003), which impedes the individuals' ability to process new information and to exploit existing knowledge which is crucial for their innovation performance. The combined effect of productivity declines of the individual inventors within the firm can be expected to impact the firms' overall innovation performance in the post-M&A period. Hence, we suggest a first baseline hypothesis:

Hypothesis 1. A decline of acquiring firms' post-M&A innovation performance is associated with an innovation performance decline of their incumbent inventors.

Financial cutbacks and elimination of redundant activities imposed after the M&A (Hitt et al., 1991; Lengnick-Hall, 1991) may translate in the relocation of inventors or a reallocation of tasks within the firm. The accompanying task uncertainty and a probable job uncertainty can result in the departure of R&D employees (Ernst and Vitt, 2000; Kapoor and Lim, 2007; Paruchuri et al., 2006). Since the locus of knowledge resides with individuals, the departure of inventors implies a direct loss of knowledge and human capital, which affects the post-M&A innovation performance of the firm (Ernst and Vitt, 2000). Hence, following prior studies we suggest a second baseline hypothesis:

Hypothesis 2. A decline of acquiring firms' post-M&A innovation performance is associated with inventor departure.

Inventor departure has gained a lot of attention in the previous literature (Ernst and Vitt, 2000; Hussinger, 2010; Kapoor and Lim, 2007; Paruchuri et al., 2006). From a KBV perspective, this effect is rather straightforward because the loss of inventors implies a loss of knowledge (Grant, 1996). However, because of inventors' interactions within the firm, knowledge of departing inventors is not completely lost, but partly remains as organizational memory (Argote and Ingram, 2003) within the firm as this knowledge is transferred to the leaving inventor's coworkers as well as to the broader intra-organizational environment (Argote and Miron-

Spektor, 2011). Explicit knowledge is, for instance, shared between individuals via communication or documentation (Polanyi, 1962; Zander and Kogut, 1995). Tacit knowledge which is more difficult to be transferred or stored is kept to some extent within the firm as individuals are exposed to the tacit knowledge of each other by observing or by working together (Grant, 1996) and by the various small activities taking place within a firm every day (Zangwill and Kantor, 1998). Knowledge can also be embedded in specific tools which can facilitate learning about tasks such as identifying patterns in data (Darr et al., 1995) or in the products and services that a firm offers (Mansfield, 1986). Another important knowledge storage mechanisms are task sequences and routines that remain part of the firm's innovation process when individual inventors leave (Argote and Ingram, 2000; Darr et al., 1995). Not at least, knowledge can be stored through the firm's corporate culture (Weber and Cramerer, 2003).

Research has further shown that the degree to which employee turnover affects firms is heterogeneous. For firms with hierarchical structures (Carley, 1992) or with clear structures (Rao and Argote, 2006) turnover of employees is less detrimental than for other firms. Most publicly listed firms that conduct acquisitions are of a significant size and well structured so that we can infer that in public firms, compared to other firms, knowledge loss through inventor departure is limited.

The effect of an M&A on inventors that remain within the firm can be expected to be larger in comparison to the effect of inventor departure. Next to the psychological boundaries to knowledge processing and exploitation that individuals face in the post-M&A period due to task and job uncertainty, an M&A affects the firm's transactive memory which defines a "shared system that individuals in groups and organizations develop to collectively encode, store, and retrieve information or knowledge in different domains" (Argote and Ren, 2012; Wegner, 1987). The meta-knowledge stored in this system provides individuals with more knowledge than what they actually possess. It allows for task specialization in groups and also fosters creativity (Gino et al., 2010). If tasks for the inventors change in the post-M&A period their knowledge about who knows what becomes partly obsolete. The effect is accelerated if parts of this knowledge system are removed, i.e. through inventors departing, as this leaves gaps in the knowledge storage and retrieval system.

In conclusion, a productivity decline of inventors who remain within the acquiring firm and who continue working with this embedded knowledge is expected to have a greater impact on innovation performance than inventor departure. Thus, we hypothesize:

Hypothesis 3. The decline of acquiring firms' post-M&A innovation performance is more strongly associated with incumbent inventors' innovation performance decline than with inventor departure.

2.2.3 Hiring new key inventors as a remedy for post-M&A productivity declines

While providing ample evidence on post-M&A innovation performance declines and their causes (e.g. Ernst and Vitt, 2000; Hitt et al., 1991; 1996; Kapoor and Lim, 2007; Paruchuri et al., 2006; Ravenscraft and Scherer, 1987), previous literature is silent about possible remedies that can be employed by the acquiring firm. We suggest the hiring of key inventors as one specific mean acquiring firms can take in order to counteract post-M&A innovation performance declines.

Individuals have been shown to be heterogeneous in terms of the knowledge they possess (Zucker and Darby, 1995; Zucker et al., 1998). Accordingly, the innovation performance distribution of inventors is highly skewed (Lotka, 1926; Narin and Breitzman, 1995; Price, 1965). Within each technological domain and each organizational context, there are some key inventors that are crucial for the process of innovation creation due to their superior technical knowledge and expertise (French & Raven, 1959), but also because of the tacit knowledge they carry (Hess and Rothaermel, 2011; Zucker et al., 2002). The significance of key inventors for corporate innovation is widely acknowledged (Zucker and Darby, 1995, Zucker et al., 2002).

Acquiring firms can hire new key inventors from outside the merged firm with superior past performance as compared to most incumbent inventors to proactively counteract innovation performance declines after M&As. Newly hired key inventors are expected to positively contribute to the process of organizational learning and knowledge creation within their new environment due to the knowledge they carry, their experience, skills endowment, and talent. The hiring of key inventors will provide the acquiring firms with access to these skills, competencies, and experiences (Rao and Drazin, 2002) and also to the knowledge gathered at their former employer (Barney, 1991). As an additional and new input to the firm's knowledge production process, we anticipate the hiring of new key inventors to have a positive effect on the firm's innovation performance. Hence, we hypothesize:

Hypothesis 4. Newly hired key inventors are positively associated with the acquiring firm's post-M&A innovation performance (direct effect).

Newly hired key inventors are also expected to have a positive impact on the innovation performance of incumbent inventors at the acquiring firm, who are often found to experience an innovation productivity decline after an M&A. KBV research of organizational learning has explored the mechanism of internal learning and transmission of information through members of an organization. Levitt and March (1988) explore different processes of knowledge diffusion and point out that transmission of information takes place through inter-personal contacts, somewhat similar to the spread of a disease. Thus, the movement of personnel, which facilitates the contact between incumbent inventors and newly hired inventors, is the main mechanism that facilitates the transmission of knowledge and organizational learning (Biggart, 1977).

This transmission mechanism is documented in the prior empirical literature (e.g., Mas and Moretti, 2009; Paruchuri, 2010; Sacerdote, 2001).[5] These studies argue that social interactions between inventors are an important channel to knowledge recombination (Nerkar and Paruchuri, 2005) and knowledge spillovers (Zucker and Darby, 1997). Since a newly hired key inventor is likely to receive a key position within the acquiring firm she will be in contact with many other inventors within the firm (Kehoe and Tzabbar, 2015; Paruchuri, 2010). Accordingly, the newly hired key inventor has more channels for knowledge dissemination as compared

[5] Other studies that relate to the influence of key inventors on their colleagues are: (1) Azoulayet al. (2010) who show that the productivity of peers decreases by 5%-8% if a star collaborator dies unexpectedly; (2) Oettl (2012) who finds that the negative effect refers in the first place to the quality of the scientists's output; and (3) Waldinger (2012) who explores the long-lasting effects on the quality of recruits of star dismissals in Nazi Germany.

to inventors in less central positions. Given their central network position within the firm (Bonacich, 1987; Krackhardt, 1990), we expect that newly hired key inventors can disseminate their knowledge within the organization both fast and effectively.

The arrival of new key inventors can counteract the discouraging effect of the M&A event on the remaining inventors at the acquiring firm. First of all, the hiring of key inventors signals the importance of innovation for the firm during the M&A period so that incumbent inventors' uncertainty about their future is reduced. By hiring key inventors, acquiring firms show their commitment to innovation which can reduce employees' concerns about their future employment, allowing them to focus more on processing new, innovative information. Second, newly hired key inventors can spur the motivation of inventors at the acquiring firm because inventors have a strong preference to work with higher qualified colleagues (Barabâsi et al., 2002; Wagner and Leydesdorff, 2005). Third, new key inventors can leverage their position and resource access to reduce task and job insecurity among incumbent inventors as they provide new leadership and strategic direction to their peers (Kehoe and Tzabbar, 2015; Paruchuri, 2010). Key inventors are regarded as innovative leaders with the ability to initiate and lead innovation efforts (Kehoe and Tzabbar, 2015), so that by working with them, incumbent inventors engage in new projects that, given the expertise and productivity of key inventors, are more likely to be successful. Not at least, newly hired key inventors can strengthen the transactive system by closing the gaps that result from inventor departure with positive implications for the incumbent inventors' innovation performance. We thus hypothesize:

Hypothesis 5. Newly hired key inventors are positively associated with the contribution of incumbent inventors to the acquiring firm's post-M&A innovation performance (indirect effect).

2.3 METHODS

2.3.1 Dataset

Our analysis is based on a large, tailor-made dataset set that draws from several different databases. It includes information on all publicly listed U.S. firms involved in M&As over the period 1980-2010 where at least one of the M&A parties is actively involved in innovation activities in the sense that it has applied for at least one patent at the United States Patent and Trademark Office (USPTO) since its foundation. Information about the M&A deals was extracted from the database Thomson One Banker provided by Thomson Reuters. We consider only those deals that were completed and which involved majority ownership. The M&A data was linked to firms' financial records which were retrieved from Compustat. The match between the two databases is based on firms' name, state, and the firms' identifiers CUSIP and PERMNO (taken from the Center for Research in Security Prices (CRSP) database).[6]

Information on the patent activity of firms and inventors is taken from the NBER patent database and the Coleman Fung Institute for Engineering Leadership database (Li et al., 2014)[7]. Patent information is matched to the firm data using each firm's identifiers and name. Data on

[6] The CRSP database tracks firms (including their names and CUSIPs) throughout their life time and provides them with a unique identification (PERMNO). We matched the Thomson Reuters' M&As database and Compustat to CRSP, assigning to both databases' firms a PERMNO. In a next step, we matched Thomson Reuters' M&A database to Compustat via PERMNO. This helped us to recover deals for which the CUSIP changed over time.

[7] Formerly the Patent Network Dataverse from Harvard Institute for Quantitative Social Science.

the mobility of inventors is taken from the Coleman Fung Institute for Engineering Leadership database (Li et al., 2014). This database assigns an inventor ID to all individuals that are listed on USPTO patent documents. Based on this ID, inventors can be traced across different firms by their reappearance on patent documents. We use patent numbers to link inventors to different firms that appear as patent applicants on the patent documents and to track their mobility. Throughout the whole data linking process, we conducted manual checks, in particular for firms for which we discovered missing or ill-defined linkages between the datasets due to misspellings of firm names or identifiers.

We keep a 9-year window around the M&A for our analysis of the M&A period (see Ahuja and Katila (2001), and Kapoor and Lim (2007) for similar choices). A 9-year window allows mapping the short time effects of the M&A. A too wide time window bears the risk to attribute performance developments which are more distant in terms of time wrongly to the M&A event. The resulting sample consists of a panel data set including 1,402 deals, corresponding to firms in 62 different industries over a 31-year period.

2.3.2 Variables

2.3.2.1 Dependent Variable

The dependent variable in our model is the firms' innovation performance. Innovation performance is proxied by the number of granted patents per year of the acquiring firm.[8] Patents are an established innovation indicator (e.g. Archibugi, 1992; Cohen and Levin, 1989;

[8] We define patent year as the application year of the granted patent because we want to measure successfully finished projects as close as possible to their completion date.

Griliches, 1990). Patents reflect the immediate result of R&D activity and hence depict successful R&D projects before the market introduction of the product (Ernst, 1995; Griliches, 1990). We use granted patents and not patent applications because the former is an indicator of successful innovation (Ahuja and Katila, 2001).[9] The advantage of this is that it provides a date that it is closer to the time in which the invention occurs and gets rid of the delays that may occur in the granting process (Ahuja and Katila, 2001; Ernst, 2001; Schmoch et al., 1988; Trajtenberg, 1990).

2.3.2.2 After M&A indicator

We use a dummy variable (After M&A) to distinguish the periods before and after the M&A. The variable is equal to zero for the years before the M&A and equal to one on the years in which the M&A occurs and thereafter.

2.3.2.3 Incumbent Inventors (INVENTORS)

We use the number of incumbent inventors as a proxy for the stock of knowledge which is the major ingredient to the patent production function (Pakes and Griliches, 1980).Our definition includes those inventors that are working at the M&A firm at the time in which the deal occurs. Due to multicollinearity concerns, we normalize the number of inventors by total assets.

[9] Often patent citations are used as a means to account for the "quality" of patents. We restrain from using patent citations as an alternative dependent variable or as a quality adjustment for the patent count variable because the M&A could impact the citation likelihood and rate of the merged firms' patents. For instance, a highly reputed target firm which changes its name after the M&A might receive fewer citations because of its decreased visibility while patent outcome and quality is unchanged. Also, a relatively unknown target might receive more citations after a merger with a highly reputed firm while patent volume and outcome remain unchanged.

2.3.2.4 Inventor Departure (DEPARTING)

The dataset provided by the Coleman Fung Institute for Engineering Leadership allows us to trace inventors over time across different organizations (Li et al., 2014). Mobility is defined based on the appearance of inventors on patent documents of different patent applicants. An inventor is defined to move from firm *i* to firm *j* when after filing the last patent application with firm *i*, she starts filing an application with firm *j*, and no longer with firm *i*. We measure departing inventors as the ratio of inventors departing the firm at time *t* over the total number of inventors at time *t*. This specification avoids multicollinearity.

2.3.2.5 Key inventors (KEY)

Regarding the concept of key inventors, previous literature has employed different definitions. There are studies that classify key inventors in terms of productivity, i.e. number of patents granted (e.g. Narin and Breitzman, 1995), or in terms of quality, i.e. number of citations (e.g. Goetze, 2010), while others use a combination of the two (Ernst and Vitt, 2000; Pilkington et al., 2009; Rothaermel and Hess, 2007). We define key inventors relative to the quality, as measured by the total number of citations their patents received in the past, of the inventors already working at the acquiring firm. As previous studies on post-M&As inventor performance (see e.g. Kapoor and Lim, 2007, and Paruchuri et al., 2006), we apply a relative definition because we are interested in depicting a newly acquired superior knowledge source from the point of view of the acquiring firm.[10]

[10] While many studies define key (or star) inventors in absolute terms (e.g. as compared to the industry average or a particular field), studies on M&As and inventors' performance do apply a relative definition, among other reasons, because they focus on a

Applying a relative definition ensures that we identify as key inventors, inventors that would most likely have a central/higher position within the firm, and thus be in a position in which their knowledge is diffused to its peers (indirect effect). In order to account for the fact that knowledge gets outdated over time, we apply a depreciation rate of 15% per year to the inventors' patents.

We chose a citation-based measure for two reasons. First, patent citations have been shown to be a proxy for the market value of innovations (Hall et al., 2005). The market value of her inventions contributes to the importance of the inventor for the firm and correlates with her access to resources. Second, forward citations reflect the technological importance as perceived by knowledgeable peers in the same technology field (Albert et al., 1991). The recognition of the so defined key inventor by her colleagues is important for her influence on her colleagues in her firm.

Further, in line with Aggarwal and Hsu (2012), we define newly hired key inventors relative to the majority of inventors that are already working for the firm. We prefer this relative definition of key inventors for two reasons. First of all, star inventors in their field of technology, as defined by Zucker and Darby (1999; 2001), are rare so that they might not show up frequently in firms involved in M&As. Second, from a conceptual point of view, we are interested in depicting inventors that are key relative to the incumbent inventors within the acquiring firm.

Regarding our specific measure, we identify key inventors as those receiving more patent citations than the top 75% of inventors of the

very specific subset of firms (i.e. firms that have incurred M&As), so that taking an absolute definition would severely reduce the number of inventors included in the study.

acquiring firm. We define key inventors who are new to the firm as the ratio of key inventors hired by the firm at time *t* over the total number of inventors at time *t* in order to avoid multicollinearity issues.

2.3.2.6 Control variables

We control for multiple factors that may affect firms' patenting output but that is not part of our theoretical focus. Previous literature has pointed out that patenting activity increases with firms' size (Cohen and Levinthal, 1989; Mansfield, 1986). Large firms may take advantage of economies of scope during the innovation process and thus have a higher patent productivity (Scherer, 1983). We include total assets (*ASSETS*) as a proxy for firm size. We take the logarithm to account for the skewness of its distribution.

Further, we use a set of year dummies in order to control for time trends in corporate patenting. Industry dummies do not explicitly enter into our specification because they are time-invariant and hence absorbed by the firm-specific fixed effects that we use.

All independent and control variables are lagged by one year in order to limit endogeneity concerns. Lagging the independent variables (innovation input) by one year is in line with previous studies that demonstrate a contemporaneous relationship between patenting (innovation output) and R&D expenditures (see e.g.: Blundell et al., 2002; Guo and Trivedi, 2002; Hausman et al., 1984; Hall et al., 1986). More recently Gurmu and Perez-Sebastian (2008) confirmed the previously found relationship and showed that the first and second R&D lags were also significant for a sample of U.S. manufacturing sector from 1982 to 1992.

2.4 EMPIRICAL FINDINGS

2.4.1 Descriptive statistics

Table 2-1 shows the descriptive statistics of the variables of interests.[11] For comparison purposes, Table 2-2 shows the means and standard deviations for our variables before and after the M&A event, as well the result for the t-test for the equality of means for both groups of observations.

Table 2-1. Descriptive Statistics.

Variable	Mean	Std. dev.	Min	Max	Obs.
Patents per year	17.58	87.13	0	1612	6105
ASSETS	6.78	2.13	0	14.45	6105
INVENTORS	0.04	0.09	0	0.69	6105
DEPARTING	0.18	0.23	0	1	6105
KEY	0.06	0.18	0	1	6105

The acquiring firms of our sample have an average of 18 granted patents per year, but with a large standard deviation. A characteristic of the distribution of patents is the right skewness and the large number of zero observations (Blundell et al., 1995). As for the before and after M&A comparison of the means, the t-test reveals no significant difference between the two periods. Acquiring firms have an average of 876 million in assets which corresponds to a log(asset) value of 6.78 with firms' assets being significantly larger after the M&A. The share of inventors is reduced

[11] See Table A1 in the APPENDIX for bivariate correlations of the main variables.

after the M&A. This might be explained by the pattern of inventors' mobility around the M&A event but also by the increase in total assets. On average, the inventor share is 4%, being smaller after the M&A than in the pre-M&A period. The t-test reveals that a significantly lower share of inventors leaves before the M&A event (16%) compared to the post-M&A period (20%). The share of new key inventors hired by the acquiring firms is about 6%, with a significantly lower hiring rate after the M&A.[12]

Table2-2.Comparison of means before and after the M&A event.

Variable	Mean before	Mean after	Std. dev. before	Std. dev. after	t-test	Significance level
Patents per year	17.3	17.84	89.26	85.08	-0.24	0.81
ASSETS	6.3	7.23	2.13	2.02	-17.51	0.00
INVENTORS	0.05	0.03	0.10	0.06	11.80	0.00
DEPARTING	0.16	0.20	0.21	0.26	-6.46	0.00
KEY	0.07	0.05	0.19	0.16	5.13	0.00

2.4.2 Regression results

We employ fixed-effects Poisson regressions with robust standard errors in order to account for the count data nature of the dependent variable and for unobserved firm-specific effects (Wooldridge, 2010). Table 2-3 presents the estimation results. The first column shows the basic specification including firms' size and the share of inventors and departing inventors as well as time dummies. In addition, a post-M&A dummy is

[12] The median tests confirm the results obtained from comparing the means before and after the M&A event. The median tests reject the null hypothesis of no difference between both groups for the dependent variable, while failing to reject the null in the case of ln(Assets), inventors' share, leavers' share and key new inventors' share.

included to test whether the patent outcome declines after the M&A. The estimated coefficients show the expected signs. We find that patent outcome is positively associated with firm size and the share of inventors. The marginal effects suggest that an increase of one in the firm size and inventor share variable leads to an increase of 13 percent (=exp(0.12)-1) and 46 percent (=exp(0.23)-1) of the number of patents, respectively. The marginal effect of inventors leaving the firm corresponds to a 19 percent decline of firm's patent output. If 18 percent of the inventors leave in the M&A period as is the case for our sample (see Table 2-1) the patent productivity decreases by 3.4 percent. Furthermore, we find that firms' innovation performance decreases in the post-M&A years; the M&A event is responsible for a productivity decline of 14 percent, which is 2.5 patents at the sample mean. Finally, the year dummies are jointly significantly different from zero, as the likelihood ratio test shows, implying that there are changes in the acquiring firms' patenting over time.

The second and third specifications include the variables capturing sources of innovation declines at the firm level after the M&A event. First, we find a significant and negative effect of the interaction term between the inventor share and the post-M&A dummy, indicating that patent productivity of inventors declines after the M&A (specification 2 and 3). This effect is in line with our baseline hypothesis 1. The change of inventor productivity after the M&A equals to -1.19 percentage points (=exp(0.33-1.92)-exp(0.33)). This corresponds to a loss of 0.21 patents at the sample mean value.[13] Second, we find a negative and significant effect of the inventors leaving the firm after the M&A supporting our baseline

[13] See Shang, Nesson and Fan (2015) for a discussion of the interpretation of interaction effects in poisson models.

hypothesis 2. Leaving inventors account for a productivity decline of 0.30 percentage points (=exp(0.07-0.33)-exp(0.07)). We also find that the productivity decline of the inventors that remain in the acquiring firm is larger than the patents lost due to inventor departure. A t-test for the equality of both coefficients shows that the difference is significant (Chi^2=139.07; p-value=0.000), which supports hypothesis 3.

The fourth and fifth specifications include the share of new key inventors before and after the M&A. The results show that while hiring a key inventor in the immediate pre-M&A years is counterproductive we find that newly hired key inventors have a significant and positive effect on the post-M&A patent outcome. The direct positive impact of newly hired key inventors on firms' post-M&A patenting output accounts for an increase of 0.148 percentage points. This finding is in line with hypothesis 4.

The last specifications present the test of hypothesis 5. In support of this hypothesis, we find that there is a positive and significant indirect association between newly hired key inventors on the patenting performance of incumbent inventors. The impact of newly hired key inventors on firms' patenting output through the positive effects on incumbent inventors accounts for 1.34 percentage points. Moreover, the positive effect of the newly hired key inventors, represented by the triple interaction term (INVENTORS* KEY *after M&A), outweighs the negative effect of the M&A on the inventors' productivity (INVENTORS*after M&A) as the test on the equality of the coefficients suggests (Chi^2=13.32; p-value= 0.000).

Table2-3. FE Poisson regression for firms' patenting output.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ASSETS	0.12***	0.11***	0.10***	0.10***	0.09***	0.10***	0.09***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
INVENTORS	0.23**	0.44***	0.33***	0.46***	0.40***	0.69***	0.57***
	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.11)
DEPARTING	-0.17***	-0.20***	0.07	-0.18***	-0.20***	-0.18***	-0.20***
	(0.03)	(0.03)	(0.06)	(0.03)	(0.03)	(0.03)	(0.03)
After M&A	-0.13***	-0.01	0.09***	-0.01	-0.05***	0.00	-0.03**
	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
DEPARTING			-0.33***				
*after M&A			(0.06)				
INVENTORS		-1.86***	-1.92***	-1.89***	-1.92***	-1.90***	-2.04***
*after M&A		(0.13)	(0.13)	(0.13)	(0.13)	(0.13)	(0.14)
KEY				-0.24***	-0.60***	-0.04	-0.38***
				(0.04)	(0.06)	(0.05)	(0.08)
*KEY**after					0.70***		0.49***
M&A					(0.07)		(0.09)
INVENTORS						-3.68***	-2.81***
* *KEY*						(0.58)	(0.76)
INV KEY*							2.43**
*after M&A							(1.15)
Observations	6105	6105	6105	6105	6105	6105	6105
Likelihood Ratio Test	2148.89	2174.72	2042.39	2180.33	2158.14	2173.95	2160.53

*Note: Table displays coefficients with standard errors in parentheses. *p<0.10, **p<0.05, *** p<0.01*

2.4.3 Further analysis and robustness checks

As a further analysis, we re-estimated the different specifications distinguishing industries according to the level of technology intensity. We followed the OECD (2011) classification and distinguish between low-tech and high-tech industries. Tables 2-4 and 2-5 show the results. Baseline hypothesis 1 holds for both groups of industries when analyzed separately. This implies that regardless of the level of technological intensity of the industry, M&As are disruptive events that negatively affect the innovation performance of inventors that remain at the firm. Inventor departure around the M&A effect has a negative effect on both subsamples. Distinguishing between leaving inventors before and after the M&A event, we find that the negative effect of departure of inventors after the M&A event (baseline hypothesis 2) is supported in the low-tech subsample but we find a positive and significant effect for post-M&A inventor departure in the case of the high-tech industries next to an overall negative effect of leaving inventors for the complete M&A period. In fact, we find that for the high tech sector inventors leaving after the M&A period have no effect on innovation performance.[14] For hypothesis 3, we find support in both subsamples indicating that incumbent inventor productivity declines supersede the effects of inventor departure. Regarding the hiring of key inventors after the M&A event (hypothesis 4), the effect is positive in high-technology sectors but negative and significant for low-technological industries. Tables 2-4 and 2-5 support the positive effect of key inventors on their peers (hypothesis 5).

[14] We test whether the departing inventors coefficient and the departing inventors after M&A coefficient were equal in magnitude, i.e. whether -068+0.69=0, and obtain that we cannot reject the null hypothesis of equality of coefficients (Chi^2= 0.03; p-value= 0.871).

Table2-4. High-Tech Sectors: FE Poisson regression for firms' patenting output.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ASSETS	0.19***	0.18***	0.21***	0.18***	0.17***	0.17***	0.16***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
INVENTORS	0.32**	0.38***	0.63***	0.38***	0.33**	1.11***	0.95***
	(0.13)	(0.13)	(0.14)	(0.13)	(0.13)	(0.14)	(0.15)
DEPARTING	-0.11**	-0.12***	-0.68***	-0.12***	-0.16***	-0.12***	-0.15***
	(0.04)	(0.04)	(0.10)	(0.05)	(0.05)	(0.05)	(0.05)
After M&A	-0.03*	0.01	-0.17***	0.01	-0.06***	0.02	-0.03
	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)
*DEPARTING**after M&A			0.69***				
			(0.10)				
*INVENTORS**after M&A		-0.62***	-0.55***	-0.62***	-0.54***	-0.64***	-0.76***
		(0.15)	(0.15)	(0.15)	(0.15)	(0.15)	(0.17)
KEY				0.03	-0.88***	0.38***	-0.27**
				(0.05)	(0.06)	(0.06)	(0.12)
*KEY**after M&A					1.28***		0.79***
					(0.11)		(0.13)
INVENTORS KEY*						-12.8***	-11.8***
						(1.19)	(1.60)
*INVENTORS** KEY *after M&A							5.76***
							(2.11)
Observations	2670	2670	2670	2670	2670	2670	2670
Likelihood Ratio Test (χ^2)	1735.02	1728.37	1722.28	1728.30	1712.87	1733.08	1719.78

*Note: Table displays coefficients with standard errors in parentheses. *p<0.10, **p<0.05, *** p<0.01*

Table 2-5. Low-Tech Sectors: FE Poisson regression for firms' patenting output.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ASSETS	0.05***	0.05***	0.01	0.04***	0.05***	0.04***	0.04***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
INVENTORS	0.46***	1.08***	0.68***	1.08***	1.11***	0.75***	0.98***
	(0.16)	(0.15)	(0.16)	(0.15)	(0.15)	(0.17)	(0.17)
DEPARTING	-0.19***	-0.24***	1.00***	-0.23***	-0.23***	-0.25***	-0.26***
	(0.04)	(0.04)	(0.08)	(0.04)	(0.04)	(0.04)	(0.04)
After M&A	0.01	0.33***	0.84***	0.33***	0.38***	0.34***	0.44***
	(0.02)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)
*DEPARTING**after M&A			-1.47***				
			(0.08)				
*INVENTORS**after M&A		-4.96***	-5.66***	-5.01***	-4.88***	-5.00***	-6.13***
		(0.24)	(0.24)	(0.24)	(0.24)	(0.24)	(0.27)
KEY				-0.36***	-0.14*	-0.66***	-0.20*
				(0.06)	(0.07)	(0.08)	(0.11)
KEY *after M&A					-0.69***		-1.53***
					(0.13)		(0.17)
INVENTORS KEY*						3.49***	0.27
						(0.59)	(0.78)
INVENTORS KEY* *after M&A							16.00***
							(1.64)
Observations	3435	3435	3435	3435	3435	3435	3435
Likelihood Ratio Test (χ^2)	2611.77	2821.24	2605.98	2741.17	2755.99	2753.91	2793.95

*Note: Table displays coefficients with standard errors in parentheses. *p<0.10, **p<0.05, *** p<0.01*

Further, to show that the performance premium is coming from newly hired inventors vs. other regular inventors, we present the different models including non-key inventors (Table 2-6). The results show that the hiring of new non-key inventors brings a positive and significant direct effect into the acquiring firm, however, non-key inventors fail to increase acquiring firms' innovation through a positive effect in their peers (the indirect effect is not significant). Moreover, the hiring of these new non-key inventors, contrary to the hiring of new key inventors, do not outweigh the post-innovation performance decline of incumbent inventors (Chi^2=147.03; p-value=0.00), which confirms the existence of performance premium derived from hiring key inventors.

Finally, to address the possible concerns regarding the underestimation of standard errors by the Fixed-Effects Poisson estimator, we re-estimate the different specifications using zero-inflated Poisson (ZIP) models, which account for the overdispersion coming from the excess of zeros in the data[15] (see Cameron and Trivedi, 2013; Lambert, 1992; Long, 1997). The ZIP model allows overdispersion through the splitting process that models the outcomes as zero or nonzero, and similar to the hurdle models, supplement the count density with a binary process (Cameron and Trivedi, 2013). As shown in Table 2-7, the results, and most importantly the significance of the coefficients of interest do not significantly change with respect to the main FE Poisson regression.

[15] In our sample, 3,476 (out of 6,105) firm-year observations have zero patent applications (approximately 57%).

Table 2-6. FE Poisson regression for firms' patenting output.

	(1)	(2)	(3)	(4)
ASSETS	0.11***	0.11***	0.11***	0.11***
	(0.01)	(0.01)	(0.01)	(0.01)
INVENTORS	0.45***	0.49***	0.28**	0.29**
	(0.10)	(0.10)	(0.11)	(0.12)
DEPARTING	-0.18***	-0.19***	-0.18***	-0.19***
	(0.03)	(0.03)	(0.03)	(0.03)
After M&A	-0.01	-0.04**	-0.01	-0.04**
	(0.02)	(0.02)	(0.02)	(0.02)
*INVENTORS**after M&A	-1.87***	-1.91***	-1.91***	-2.05***
	(0.13)	(0.13)	(0.13)	(0.16)
NEW NON_STARS	-0.02***	-0.07***	-0.02***	-0.09***
	(0.01)	(0.01)	(0.01)	(0.01)
*NEW NON_STARS**after M&A		0.07***		0.07***
		(0.01)		(0.01)
*INVENTORS *NEW NON_STARS*			0.25***	0.30**
			(0.08)	(0.12)
*INV*NEW NON_STARS**after M&A				0.10
				(0.15)
Observations	6,105	6,105	6,105	6,105
Likelihood Ratio Test (χ^2)	2780	2818	2791	2840

*Note: Table displays coefficients with standard errors in parentheses. *p<0.10, **p<0.05, *** p<0.01*

Table 2-7. Zero-Inflated Poisson regression for firms' patenting output.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ASSETS	0.19***	0.18***	0.18***	0.17***	0.15***	0.17***	0.15***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
INVENTORS	0.94***	1.05***	1.02***	1.10***	1.03***	1.34***	1.12***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.12)
DEPARTING	-0.08***	-0.10***	-0.03	-0.07**	-0.10***	-0.07**	-0.10***
	(0.03)	(0.03)	(0.06)	(0.03)	(0.03)	(0.03)	(0.03)
After M&A	-0.26***	-0.18***	-0.15***	-0.17***	-0.22***	-0.17***	-0.21***
	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
*DEP**after M&A			-0.08				
			(0.06)				
INV*after M&A		-1.14***	-1.16***	-1.21***	-1.24***	-1.23***	-1.41***
		(0.13)	(0.13)	(0.13)	(0.13)	(0.13)	(0.15)
KEY				-0.46***	-0.97***	-0.28***	-0.81***
				(0.04)	(0.06)	(0.05)	(0.09)
*KEY**after M&A					0.89***		0.70***
					(0.07)		(0.10)
*INVENTORS**						-3.61***	-1.81**
KEY						(0.59)	(0.74)
*INV*KEY**							3.32***
after M&A							(1.27)
Observations	6,105	6,105	6,105	6,105	6,105	6,105	6,105
Deal Dummies	YES	YES	YES	YES	YES	YES	YES
Time Effects	YES	YES	YES	YES	YES	YES	YES
Model chi-square	304192	304271	304273	304413	304557	304456	304566

*Note: Table displays coefficients with standard errors in parentheses. *p<0.10, **p<0.05, *** p<0.01*

2.5 DISCUSSION

Although M&As are acknowledged as an important means to access innovative assets and know-how, innovation performance often declines in the post-M&A period (Comanor and Scherer, 2013; Hitt et al., 1990, 1996; Ornaghi, 2009; Valentini, 2012; Veugelers, 2006). We investigated the reasons for these post-M&A innovation declines by focusing on individual inventors as the sources of firms' innovation performance. We further suggested the hiring of new key inventors after the M&A event as a remedy for declining innovation performance.

Our results show that post-M&A innovation performance declines are driven by both a lower contribution of the inventors that remain with the merged firm and by the loss of contributions of departing inventors. Inventor departures imply a downsizing of the firm's knowledge base with direct implications for innovation performance. The lower productivity of incumbent inventors that remain within the firm suggests that there are significant barriers to further knowledge exploitation after an M&A event. Strategic reconfiguration and restructuring (Karim and Mitchell, 2000), high fluctuations rates of personnel and changes in job definitions (Ernst and Vitt, 2000; Walsh, 1988) create a sense of dislocation (Cartwright and Cooper, 1993; Paruchuri et al., 2006). This impacts the cognitive ability of inventors (Fugate et al., 2008), who have to cope with the new and disruptive situation rather than processing relevant work-related information (Fugate et al., 2008; Staw et al., 1981) and as such this creates a cognitive barrier to knowledge exploitation (Jensen and Szulanski, 2004; Minbaeva et al., 2003).

An interesting result of our research that qualifies previous work (Ernst and Vitt, 2000; Kapoor and Lim, 2007; Paruchuri et al., 2000) indicates that firms' declining post-M&A innovation performance is to a larger extent associated with the lower contribution of incumbent inventors that remain with the merged firm than with the loss of contributions by leaving inventors. This result is in line with organizational learning theories that emphasize the importance of the transactive memory (Argote et al., 2011; Wegner, 1987). With changing tasks and structures within the firm, an M&A renders the knowledge stored in the firm party obsolete with negative implications for inventors' innovation performance. This effect is accelerated by inventor departure which leads to a gap in the firm's transactive memory.

One of the measures that firms can take to enhance their innovation performance after an M&A is the hiring of key inventors (Almeida and Kogut, 1999; Ganco, 2013; Groysberg and Lee, 2009; Rosenkopf and Almeida, 2003; Singh and Agrawal, 2011). The hiring of new key inventors in the post-M&A period is associated with lower levels of post-M&A innovation performance declines. The hiring of key inventors affects innovation performance in two ways. On the one hand, there is a direct effect in the sense that these newly hired key inventors increase innovation performance after an M&A by increasing the knowledge base of the acquiring firm and, hence, accelerating the firm's innovation performance. The newly hired key inventors provide the acquiring firm with new skills, competencies, and experiences (Rao and Drazin, 2002), gathered at their former employer (Barney, 1991; Groysberg et al., 2008). On the other hand, newly hired key inventors improve the productivity of the inventors already working for the acquiring firm. This implies that newly hired key inventors do not only add to a firms' existing knowledge base (Rao and Drazin, 2002) but that they also improve the further exploitation of the existing knowledge base (Hackman, 2002). Hiring new key inventors sends a positive signal to incumbent inventors, reassuring that innovation is of importance to the firm, even in times of corporate restructuring. As inventors have a strong preference to work with higher qualified colleagues (Barabasi et al., 2002; Wagner and Leydesdorff, 2005), newly hired key inventors can also increase the motivation and productivity of incumbent inventors (Allison and Long, 1990). In addition, newly hired key inventors can leverage their central position in the firm and their resource access to facilitate the innovation process within the firm. Overall, this suggests that an appropriate hiring policy for external key inventors can counteract innovation declines in the aftermath of an M&A.

The contribution of a new arriving key inventor to the knowledge base of the acquiring firm is more significant for low tech firms than for high tech firms. Incumbent inventors can, hence, learn more from incoming key inventors in these sectors. In contrast to the main results and the results for the high tech sector, we do not find evidence for a direct effect of new key inventors for post-M&A innovation performance in low tech sectors. This finding which is in line with Groysberg et al. (2008), who analyze security analysts, might be explained by the lack of infrastructure, complementary work practices (Ichniowskiet al., 1997; Peteraf, 1993) and qualified co-workers (Groysberg et al., 2008; Hackman, 2002) for incoming key inventors that would allow them to exploit their knowledge immediately after arrival.

2.5.1 Managerial Implications

While descriptive, our results suggest that managerial attention during the M&A period should focus rather on the inventors that stay with the firm than on the inventors that are departing. When disentangling the sources of knowledge that contribute to firms' innovation performance incumbent inventors are associated with the larger share of innovation performance declines. This can be seen as good news for managers because it is relatively easier to foster and support the innovation activities of inventors that stay than to design attractive contracts for those inventors that are planning to leave the firm. In fact, appropriate internal policies to foster innovation can also stop inventors from departing (Groysberg and Lee, 2010). Our results further suggest that a clever hiring policy for external key inventors can help overcome the often found negative effect of M&As on innovation.

Despite the endogeneity challenges of our paper, our results seem to be supported by previous studies and anecdotal evidence. Dixon and Nelson (2005) report that human resource professionals are often not involved in the M&A planning and execution team which is typically almost entirely comprised of people from finance, IT, and other disciplines seen as essential to making the deal work. As shown by the acquisition of Gillette by P&G, an integration team that monitors and manages the M&A process can prevent declining benefits from an M&A. To avoid brain drain and to ensure continued pre-M&A levels of innovation, P&G conducted a successful key-inventors' hiring policy. Following this strategy, P&G-Gillette is regarded as one of the most successful M&As in the recent past (Kanter, 2009).

2.5.2 Limitations

As any, our study is not free of limitations. First, the analysis presented in this paper has to be considered as somewhat descriptive. The results have to be interpreted as associations rather than as causal effects. The reason is that the effects that we analyze occur in an endogenous system of strategic choices. Firms selectively decide to engage in M&As and they do so for various reasons. Around the M&A event, major organizational and strategic decisions are taken, sometimes while managerial attention being absorbed by the M&A event itself. We addressed the endogeneity concerns of leaving and newly hired inventors to some extent by using lagged variables as regressors.[16] A further limitation that our study shares with the majority of inventor mobility studies (Ge et al., 2016; Hoisl, 2007; Li et al., 2014; Trajtenberg et al., 2006) is that we can only define mobility based on patent documents. So, we miss the mobility of inventors that change their job without patent documentation. Furthermore, we cannot distinguish inventors who change their job from those that retire. We experimented with an alternative method to define inventor mobility based on their LinkedIn profile (Ge et al., 2016), but the overlap with our firm database was very small. The mobility definition that is more established in the literature turns out to be more suitable for our study.[17] Finally, given the more general perspective

[16] We further experimented with instrumental variables regressions, but were not able to find instrumental variables that were appropriate from a statistical as well as from a conceptual point of view. We were, however, able to address the selection of firms into the M&A event in a specific year using selection models with previous M&A activities within the same industry as an exclusion restriction. The results did not change and are available upon request.

[17] Ge et al. (2016) propose an alternative for tracing inventor mobility using the internet platform LinkedIn. Their approach however suffers from several drawbacks as well. First, a problem of self-selection bias arises from the fact that in LinkedIn inventors are the ones that create the profile and can choose to keep it private. Ge et al. (2016) only observe those inventors that have created a profile and decide to make it public. Second, since inventors are the ones that provide the information, there exists the possibility that they provide misleading, wrong or a lack of complete information. Inventors may, for instance, purposefully decide not to include some of their previous jobs on their profiles. Nevertheless, we made an effort to use the LinkedIn approach proposed by Ge et al. (2016) as an alternative to trace mobility of inventors in our dataset. It turned

of our study, for future research, it would be interesting to complement our large sample findings with in-depth case study evidence. Case studies do allow a deeper investigation into the different roles that incumbent inventors and newly hired key inventors play in the innovation process after an M&A.

2.6 CONCLUSIONS

Our study contributes to the literature that illustrates the importance of the transferability of knowledge across and within firms through individual talents (Kim, 1997; Song et al., 2003; Zander and Kogut, 1995) and to the literature on the role of key inventors for knowledge exploitation. We add to the prior literature by showing that key inventors play an essential role in knowledge transfer also for firms in periods of reorganization and that, as such, they can mitigate negative innovation performance effects in post-M&A periods.

Interestingly, our understanding of the crucial role of newly hired key inventors, who are both directly and indirectly associated with the post-M&A innovation performance of firms, echoes the classical statement by Joseph Schumpeter who mentioned that "… innovations are always associated with the rise to leadership of New Men …" (and women, we would like to add) (Schumpeter, 1982(1939), p. 96). These newly hired key inventors act as Schumpeterian agents of change who not only alter existing routines and introduce and generate new knowledge that impacts

out that the overlap of all inventors registered on our firms' patents and the inventors in the sample provided by Ge et al. (2016) was very small. From the 488,765 inventors that we identified from the NBER and the Coleman Fung Institute database, only 6,678 could be found in their database using the unique inventor id provided in both datasets; from the 1,402 target and acquiror firms we have in our database, only 164 targets 427 acquirors are identified; and from the 864,832 patents our dataset covers, theirs only contains 24,812. Because of these shortcomings, we decided to follow previous literature (e.g. Hoisl, 2007; Parachuri et al., 2006; Trajtenberg et al., 2004) and use the patent data as indicator for mobility.

the innovation performance of the firms, through their key position within the firm, but they can also use their leadership position to disseminate knowledge to others, to motivate colleagues, and to create an innovative environment within the firm.

CHAPTER 3

KNOWLEDGE DIFFUSION THROUGH M&AS

3.1 INTRODUCTION

Competition authorities carefully scrutinize announced mergers and acquisitions (M&As) because of the potential negative consequences in product markets as well as innovation in the industry (e.g. Ornaghi, 2008, Comanor and Scherer, 2013 and Szücz, 2014, Haucap and Stiebale, 2016). A merged firm could exploit a dominant position in a market by increasing consumer prices or by taking advantage of a superior bargaining position in upstream and downstream markets. As for the effects of M&As on innovation, a dominant position in the product market can reduce incentives to invest in research and development (R&D) for the merging parties due to a lower level of competition (Arrow, 1962; Reinganum, 1983). Innovation by competitors can be affected as well due to a reduced business stealing effect (Haucap and Stiebale, 2016).

While competition authorities have traditionally understood M&As' anti-competitive effects as a rise in the (quality-adjusted) prices of goods and services (Comanor and Scherer, 2013; Gilbert and Greene, 2015; Katz and Shelanski, 2007), recent regulations have acknowledged the potential effects of M&As on innovation. First, as a footnote to the 1990's guidelines, and then as a separate section in the 2010 U.S. Horizontal Merger Guidelines (2010 U.S. Horizontal Merger Guidelines, section 1, 6, 6.4. and 10). These guidelines recognize M&As as a potentially anticompetitive mechanism affecting innovation (2010 U.S. Horizontal Merger Guidelines; Gilbert and Green, 2015). Since the first appearance in the U.S. Horizontal Merger Guidelines in 1990, the U.S. Department of Justice (DoJ) and the Federal Trade Commission (FTC) have increased the number of challenged cases citing innovation concerns as well as the weight given to innovation concerns when taking their decisions (Gilbert and Greene, 2015). [18] In order to prevent negative implications for innovation, U.S. competition authorities have often only allowed the M&A when merging firms divest a specific innovative business line. For instance, the DoJ required DuPont and Dow Chemical Company to divest DuPont's market-leading Finesse and Rynaxypyr crop protection products in order to allow the merger between the two (DoJ, 2017).[19] The remedy sought by the DoJ included the divestiture of all intangible assets such as patents, trademarks, technical information, software, know-how, trade secrets, and designs, and tangible assets such as manufacturing equipment, tools, fixed asset, supplies, furniture and materials (DoJ, 2017). In essence what these remedies seek is to transfer the knowledge assets and equipment from the merging parties to a third

[18] Between 1990 and 1994 only 3% of the challenged cases cited innovation concerns (a total of 4 cases). This number raised up to 18% in the period 1995-2000 (but no definite M&A decision was based on innovation grounds), reaching approximately 30-35% of the cases afterwards (Gilbert and Greene, 2015). In particular, in the period 2004-2014, the DoJ challenged 30 mergers (of a total of 86 challenges) and the FTC challenged 54 mergers (of a total of 164 challenges), with about 83% of those cases concerning firms in high tech industries (Gilbert and Greene, 2015).

[19] Since Dow and DuPont are the main competitors in the markets for broadleaf herbicides for winter wheat and insecticides for chewing pests, the DoJ's complaint alleged that the loss of competition derived from the merger would result in higher prices, less favorable contractual terms, and a reduced incentive to innovate for each of these products (DoJ, 2017).

party to ensure these assets are exploited and continue generating innovations.

Another strand of the literature rooted in the field of management science proclaims that a major obstacle for the merging firms to realizing innovation gains is the departure of the inventive labor force in the post-merger years (Ernst and Vitt, 2000; Paruchuri et al., 2006; Kapoor and Lim, 2007; Arroyabe et al., 2016). Human capital, i.e. the knowledge, skills and expertise embodied in individuals (Becker, 1975; Coff, 2002; Hatch and Dyer, 2004), is a valuable asset of the firm, as knowledge workers are the sources of firms' knowledge and are responsible for firms' new ideas and innovations (Campbell et al., 2012; Coff, 1997; Lippman and Rumelt, 1982). The studies cited above suggest that M&As trigger inventor departure leading to knowledge diffusion.

Focusing on the period before the new U.S. merger guidelines were effective, this paper investigates whether and to which extent M&As represent a mechanism of knowledge diffusion through mobile inventors (Kogut and Zander, 1992; Schumpeter, 1982). We are particularly interested in the question of where are departing inventors leaving to after M&As. Empirical results for publicly listed U.S. firms involved in M&As in the period 1980-2010 show that 4% of the inventive labor force leaves around the acquisition event. We find that this mobility mainly occurs to firms with similar characteristics as the M&A firms. 63% of the mobile inventors leave to firms within the same industry and 76% to firms with a similar technological profile as the former M&A employer. Nevertheless, we also observed that about 20% of mobile inventors in the high-tech sector change industries within the high tech sectors and about 15% move from high tech industries to medium-low tech industries. While we find that the probability of going to firms with lower patent productivity to be diminishing with experience and inventors' patenting output, the results show that top patenting inventors and mature inventors also move to firms with a lower patenting profile. Our results also show that non-compete agreements facilitate the flow of inventors to firms with lower patent productivity.

This evidence is of relevance from the policy point of view as current regulations mainly consider the potential effects that M&A-induced changes might have in the innovation activities of the merged entities, overlooking potential effects that the M&A may have on the innovation activities of third non-merging parties (Haucap and Stiebale, 2016). In particular, it overlooks the potential knowledge redistribution and innovation diffusion effects of M&As on non-merging firms, which this paper shows to occur as well without the intervention of competition authorities.

3.2 THEORY & HYPOTHESES

3.2.1 M&As and innovation

The controversy about the effect of M&As on innovation traces back to the seminal work on the effect of market concentration on innovation by Schumpeter (1942) and Arrow.[20] Schumpeter (1942) advanced the hypothesis that market power and firm size are conducive to innovation because the firm can expect monopoly rents and benefit from economies of scale. Arrow (1962) took the opposite stance arguing that

[20] Survey on the theoretical literature are provided by Gilbert (2006) and Tirole (1988).

competition facilitates innovation in order to protect its current market position.[21]

On the one hand, as M&As increase market concentration and firm size, the predictions about their effect on innovation are ambiguous as well. In line with Schumpeter (1942), the first prediction is an increase in innovation after an M&A. By increasing firm size, M&As may allow benefiting from economies of scale by spreading fixed costs over more output as well as of economies of scope by reaping benefits from the diffusion of knowledge across different corporate units. The merger-induced increase in market concentration allows firms to realize efficiency gains and to further develop their innovation capabilities so that they can conduct more costly and more complex innovation projects (Cohen and Levin, 1989; Röller, 1988). In addition, complementarity effects of merging partners' technology assets may be realized increasing the incentives to innovate. Complementarity effects can arise from the combination of knowledge embodied in the inventive labor force of both companies or by the combination of both firms' intellectual property rights portfolio (Ahuja and Katila, 2001; Cassiman et al., 2005; Cloodt et al., 2006; Grimpe and Hussinger, 2008; 2014) and by accessing the technological competencies and capabilities of the acquisition target (Granstrand and Sjolander, 1990; Chaudhuri and Tabrizi, 1999). In fact, incumbent firms with their documented difficulties with disruptive (Christensen, 1997) and radical innovation (Henderson and Clark, 1990) often use acquisitions as a way to access innovation from the acquisition target. M&As also grant merging firms the opportunity to reallocate and

[21] Aghion et al. (2005) showed that both relationship can coexist. Competition always facilitates innovation in industries characterized by "neck-to-neck" competition, whereas in "unleveled industries" showing a clear pattern of leaders and laggards competition reduces innovation since laggards expect a reduction in their post-monopoly rents.

reorganize their R&D efforts across different units and to refocus their R&D strategy (Capron and Guillen, 2009). Not at least, M&As can help the merged firm to save duplicated research efforts and to internalize R&D externalities (Arrow, 1962; Katz, 1986; D'Aspremont and Jacquemin, 1988).

On the other hand, in line with Arrow (1962), the second and contrary prediction states that M&As reduce competition thereby decreasing incentives to innovation (Arrow, 1962). This is because greater market power and reduced competition in product markets discourage merging firms from innovating as they shy away from cannibalizing profits from their existing products (Reinganum, 1983). The fact that M&As allow the merging firms to save duplicated research effort must not necessarily imply that the resources are used to strengthen innovation capabilities. Firms can also use the free resources for other activities hence reducing their overall innovation efforts. This is more likely to occur if the merging firms are product market rivals (Cassiman et al., 2005). The possibility to coordinate R&D investment will also lead to lower R&D investment levels unless the technology regime is characterized by low appropriability (Kamien and Schwartz, 1982). Post-merger innovation can also be reduced in the short term due to an increase in bureaucracy costs as a consequence of the sharp increase in firm size (Arrow, 1974; Hannan and Freeman, 1977) and due to problems that are directly associated with the implementation of the M&A that absorbs resources and managerial attention (Caves, 1989; Hitt et al, 1990).

Competition law takes the perspective of Arrow (1962) treating M&As as potentially harmful for innovation. This view is supported by numerous empirical studies that have shown that M&As hamper the innovation activities of firms in the short-run (e.g. Cassiman et al., 2005; Hall, 1990, 1999; Lichtenberg, 1992; Prichett, 1985; Ravenscraft and Scherer, 1987; Veugelers, 2006). Ornaghi (2008) and Comanor and Scherer (2013) for the U.S. pharmaceutical industry, Hitt et al. (1991) and Szücs (2014) for U.S. M&As across different industries, Haucap and Stiebale (2016) for M&As affecting European product markets, and Stiebale and Reize (2011) for German acquisition targets.

3.2.2 M&As as a triggering factor of inventor departure and knowledge diffusion

One channel highlighted by previous literature by which post-merger innovation of the merging entity is reduced is the departure of inventors. Knowledge is a key strategic resource for the firm (Grant, 1996), and individuals, as the sources of knowledge and talent (Cyert and March, 1983; Grant, 1996), carry important knowledge essential for the innovation processes of the firm (Felin and Hesterly, 2007; Paruchuri et al., 2006; Rao and Drazin, 2002). The departure of inventors represents an impediment to the post-M&A innovation success (Ernst and Vitt, 2000; Paruchuri et al., 2006; Kapoor and Lim, 2007; Arroyabe et al., 2016).

M&As often imply a shift of managerial attention from daily business activities, including innovation, to the management of the M&A event (Hitt et al., 1990) and disruptions to the R&D process and organizational routines (Haspeslagh & Jemison, 1991; Puranam et al., 2006; Ranft and Lord, 2002). Financial constraints imposed by the acquisition investment (Hitt et al., 1991; Hitt et al., 1996; Miller, 1990), cost-saving programs aimed at eliminating duplicative research efforts

(Lengnick-Hall, 1991; Veugelers, 2006) and problems regarding the post-M&A integration (Haspeslagh and Jemison, 1991; Jemison and Sitkin, 1986; Pritchett, 1985, Chatterjee, 1986; Hitt et al., 1991) may trigger inventor departure. Prior research reports that up to 50% of the key inventors leave after an M&A (Ernst and Vitt, 2000).

Inventors may depart when their skills are no longer required in the merged firm or in search for new job opportunities in safer working environments (Gold, 1987; Olson, 1990; Miller, 1990). Previous research has shown that particularly key scientist, whose higher performance facilitate the job search process are more likely to leave in the aftermath of an M&A (Ernst and Vitt, 2000; Paruchuri et al., 2006; Roberts and Mizouchi, 1989). Moreover, departing key inventors foster as well the departure of their co-workers when they decide to start their own business (Lindholm, 1994).

When they depart, knowledge workers take with them the accumulated tacit and explicit knowledge gathered through their personal experience and by observing and working with their colleagues or through informal interactions, e.g. conversations that allow for information sharing (Nonaka, 1994; Palomeras and Melero, 2010; Rosen, 1972). In the context of innovative activities, tacit knowledge is of particular relevance as non-codifiable knowledge is the basis underlying inventions (Hoetker and Agarwal, 2007; Palomeras and Melero, 2010; Winter, 1986). Leaving employees may also carry with them key routines, which facilitate recipient firms to break away from their (path-dependent) technological trajectories (Mawdsley and Somaya, 2016; Song et al., 2003; Tzabbar, 2009), and structural relational capital, which refers to the external information networks and ties with former colleagues (Mawdsley and

Somaya, 2016) that generates an ongoing channel of learning and knowledge spillovers between former and new employer (Agrawal et al., 2006; Rosenkopf and Almeida, 2003; Rosenkopf and Nerkar, 2001; Singh, 2005).

Thus, the movement of individuals between firms supposes an effective transfer of knowledge across organizations (Argote and Ingram, 2000; Song et al., 2003; Moen, 2005) and mobility represents an important channel of knowledge diffusion (Arrow, 1962) as well as a way to gain access to immobile knowledge from other firms (Dosi, 1988; Teece, 1982; Winter, 1986).[22]

The knowledge diffusion generated by the departure of inventors in the merger period implies that despite the changes in market structure that M&As may bring, the overall effect of M&As on innovation may not necessarily be negative. On the one hand, as competition authorities acknowledge, innovation of the merging parties may be reduced due to the lower incentives to innovate derived from a greater market power, but on the other hand, the departure of inventors to third parties serves as an innovation redistributing channel that may spur innovation in other firms within and across industries. This is especially the case if inventors leave to firms with a weaker technological profile or to firms in different industry sectors. Both directions of mobility are facilitated by the existence of non-compete agreements (Marx, 2011). In the sections to come, we explore to which extent inventors leave after M&As and where they leave to.

[22] Kim (1997), Saxenian (1990) and Rogers and Larsen (1984) provide qualitative evidence of knowledge diffusion between semiconductors firms associated with interfirm mobility of engineers and scientists. Almeida and Kogut (1999) and Song et al. (2001) show that hiring firms receive a significantly larger number of citations to patents from the former employer.

3.3 DATA & VARIABLES

3.3.1 Dataset

Our analysis relies on a large, tailor-made dataset set constructed from different databases. It comprises all publicly listed U.S. firms involved in M&As over the period 1980-2010. We obtained information on the M&A deals from the database Thomson One Banker provided by Thomson Reuters. We only consider those deals that were completed and which involved majority ownership, and for which at least one of the M&A parties is actively involved in innovation as measured by a positive patent stock. We linked the M&A data to firms' financial records, extracted from Compustat, via firm name, state, and the firm identifiers CUSIP and PERMNO (taken from the Center for Research in Security Prices (CRSP) database).

Information on the patent activity of firms is taken from the NBER patent database and the Coleman Fung Institute for Engineering Leadership database (Li et al., 2014). Patent information is matched to the firm data using each firm's identifiers and name. Data on the mobility of inventors is taken from the Coleman Fung Institute for Engineering Leadership database (Li et al., 2014) and the United States Patent and Trademark Office (USPTO). The Coleman Fung Institute assigns a unique inventor ID to all individuals that are listed on USPTO patent documents (Li et al., 2014). Based on this ID, we trace inventors across different firms by their reappearance on patent documents and we link inventors to different firms that appear as patent applicants on the patent documents (Trajtenberg et al., 2006). Throughout the whole data linking process, we conducted manual checks, in particular for firms for which we discovered missing or ill-defined linkages between the datasets due to misspellings of firm names or identifiers.

Following previous studies (e.g. Almeida and Kogut, 1999; Hoisl, 2007; Trajtenberg et al., 2006; Song et al., 2003), we locate inventors' employers through patent data; patent documents provide information on inventors' location, assignee –which is usually a firm–, at the time of invention. Since we are interested in the mobility of inventors around the M&A event, we focus on the subsample of inventors that is affiliated with M&A firms in the 5 years prior to the occurrence of the M&A, and that are still active in the 5 years after the M&A.[23] We drop those inventors that are involved in more than one M&A deal, and those inventors who only possess one patent[24] as it is not possible to observe whether they are mobile or not. The resulting sample consists of 474 deals and 18,868 inventors in 45 different industries over a 29-year period.

3.3.2 Variables

3.3.2.1 Inventor mobility

The dependent variable for the first stage analysis is a dummy variable that captures the mobility of inventors from an M&A firm to a new firm. An inventor is defined to move from M&A firm *i* to firm *j* when after filing the last patent application with M&A firm *i*, she starts filing an application with firm *j*, and no longer with M&A firm *i*, in the 5-years after the M&A event. Our definition of mobility excludes moves from target

[23] This restriction avoids bias coming from (1) inventors that move but do not appear in any patent documents after the M&A event, or (2) inventors that do not move but do not appear in any patent documents after the M&A event (Hussinger, 2012). The inventors that disappear from our sample (i.e. cannot be traced after the M&A event) represent about 66% of the total pool of inventors (44,348 inventors). This is in line with previous studies such as Paruchuri et al.(2006) –the most overlapping study with ours in terms of database-, who for the US pharma industry (1979-1994) have a 73% of disappearing inventors.

[24] From the raw (uncleaned) database, inventors with one patent represented about 47.5% of the total number of inventors contained in the database (with the restrictions mentioned above).

firm to acquiror firm, and vice-versa as this does not capture knowledge diffusion beyond the merging firms.

Inventor individual characteristics have been shown to play an important role in inventors' mobility patterns (Campbell et al., 2012). Previous studies on mobility have pointed out that productivity of individual inventors is related to mobility (Zucker et al., 2002; Palomeras and Melero, 2010; Hoisl, 2007; Hussinger, 2012; Ganco, 2013). Hence to take into consideration the impact of inventors' productivity on mobility around the M&A event, we include various measures that reflect the productivity of inventors, both in terms of quality and quantity, as well as experience. First, and following previous studies that point out to the effect of inventors' experience on departure (Jovanovic, 1979; Topel and Ward, 1992; Paruchuri et al., 2006; Hoisl, 2007; Campbell et al., 2012), we include a proxy for inventor's experience by using patenting tenure, measured as the difference in years between inventor first patent filing and the time of the M&A. Second, we include inventors' patent stock at the time of the M&A event. This is intended to take into account the past innovation performance of the inventor and is calculated as follows:

$$patstock_{i,\,t} = patstock_{i,\,t-1}(1-\delta) + patent\ granted_{\,i,\,t}$$

where δ represent the depreciation rate of knowledge, which following previous literature, we set to 15% (Hall, 1990). Third, to measure individuals' output quality, we consider the citation stock. As compared to simple patent counts measures, such as patent stock, citation-based measures try to incorporate the economic and technological importance of patents (Jaffe and Trajtenberg, 2002). Previous studies have related patent citations with firms' market value (Hall et al., 2005), consumer surplus

(Trajtenberg, 1990), external expert evaluation of patents' value (Albert et al., 1991) and patent renewal rates (Harhoff et al., 1999). Hence, individuals' patent citations provide an indication of which inventors are more capable of bringing value to the firm, and which represent a higher human capital for the firm. We define the citation stock of an inventor as the number of citations an inventors' patent portfolio has received up to the date of the M&A, and similar to the definition of patent stock, we apply a 15% depreciation rate (Hall et al., 2005).

3.3.2.2 Destination firms' characteristics

On the second stage of the analysis, we seek to define the patterns of mobility of the inventors. For this purpose, we generate a set of dummy variables that reflect the probability that the departing inventor starts working at a firm with certain characteristics relative to the M&A departing firm. The first variable is a dummy equal to one if the inventor's former M&A employer and new firm operate in the same industry (as defined on a two-digit SIC level). The second and third variables compare the technological leadership position, in terms of patents, of the departing M&A firm relative to the new firm. The technological leadership position is defined as the location of the firm within its industry distribution of patents in the year of the M&A. For every year in our sample, we identify in which patenting quartile each of the firms of interest is located. With this information, we generate two dummy variables: (1) taking the value one if the departing M&A firm is higher positioned, i.e. a higher quartile, in the distribution of patents within its industry as compared to the position of new firm in the distribution of patents of its own industry; (2) taking the value one if the departing M&A is positioned in the same patent quartile as the new firm.

3.3.2.3 Firm-level control variables

A set of control variables is used in order to control for characteristics of the M&A firms, industry and regulations that may affect inventor's mobility. At the firm level, we control for the technological intensity of the M&A firms using the OECD (2011) classification and distinguishing between (1) low-tech, (2) medium-low, (3) medium-high, and (4) high-tech industries. We control for the scientific personnel turnover with the ratio of inventors departing the M&A firm to the total number of inventors of the M&A firm on the year of the M&A. We also control for possible effects of non-compete agreements on the patterns of mobility. Non-compete agreements are contractual provisions that prevent employees from joining a competitor or starting a business that competes with the former employer within particular industries and geographic locations for a period of time (Gilson, 1999; Marx et al., 2009). We include a dummy variable that takes the value one if on the year in which the inventor departs the firm a non-compete agreement impairing mobility within the same industry was in place in the state in which the inventor was working at the M&A firm. Further, we use a set of year, and industry dummies in order to control for time trends and industry-specific effects that may determine inventors' mobility patterns.

3.4 EMPIRICAL RESULTS

3.4.1 Econometric model

Our empirical analysis is divided into two parts. The first part focuses on the determinants of inventor departure. The second part focuses on where do the inventors move to, conditional on having departed. In this second part, we analyze the factors that determine inventors' mobility to a particular type of firm.

In both analyses, we need to control for sample selection. In the first step, we need to control for those inventors that disappear after the M&A while estimating the likelihood of inventors leaving the firm. As outlined above, inventors may retire, die or change career. Ex-ante we, hence, cannot exclude that the group of inventors that disappear is non-random and have to assume that disappearance correlates with inventor characteristics. For instance, if most inventors would retire their disappearance would be a function of their experience which would then bias our mobility estimation. In order to deal with this problem, we estimate Heckman selection models for binary dependent variables (Heckman, 1979; Van de Ven and Van Praag, 1981).

Selection models typically require an exclusion restriction, i.e. a variable that correlates with the likelihood to disappear but not with the likelihood to move. We use the number of names of the inventor (i.e. first names plus middles names plus last names) as exclusion restriction for our model. Inventors' names are the most distinguishable attribute in the process of inventor disambiguation (Li et al., 2014). Inventors possessing more than the standard first name and last name may be easier to disambiguate and hence to trace as their middle names or extra last names provides an additional feature that distinguishes from the rest of inventors (Li et al., 2014).

In the second part of the analysis where we investigate which type of firm inventors are leaving to, we need to control for those inventors that do not leave the firm. Similar to the first part, we set up a Heckman selection model that estimates the likelihood of inventors departing the M&A firm, contingent on not having disappeared and using as exclusion restriction the proportion of inventors that depart the M&A firm. The fact that a large share of inventors leaves the firm after an M&A might signal that the firm is closing down an R&D line or that there are substantial post-M&A implementation problems. A general tendency to leave after an M&A should impact the decision of an individual inventor as the underlying reasons most likely also apply to her. This variable should not affect the direction of her mobility though. This is because it is inventor's individual characteristics that determine the destination firm as a consequence of the employer-employee quality match process (Campbell et al., 2012; Hoisl, 2009; Jovanovic 1979; Marx et al., 2009; Topel and Ward, 1992).

We use different dependent variables to determine where the inventors go, controlling for the mobility of inventors. Both probit equations are modelled as a function of inventors' performance and experience, and control variables at the firm and industry level.

3.4.2 Descriptive statistics

Table 3-1 presents the descriptive statistics. The final sample consists of a total of 44,348 disappearing inventors, and 18,868 non-disappearing inventors, of which 842 move to a different firm after the M&A. This means that on average about 4.46% of the inventors leave around an M&A.

On average, inventors that are active after the M&A have an experience of 5 years, with inventors staying at the M&A firm having a slightly higher experience. Active inventors have, at the moment of the M&A, an average patent stock of 3.6 and of 4.81 for inventors that stay and depart, respectively. Inventors that depart the M&A firm have an average citation stock of 18.5, while inventors that stay at the firm have a significantly lower average at 11.75. Similar patterns are observed for the patent stock to experience ratio and citations to patent ratio, with disappearing inventors having lower values for these indicators. The differences in inventors' output and experience across groups are significant as is shown in columns (A) and (B).

As for the M&A firms' characteristics, the largest cohort of firms is located in medium-high tech industries and high-tech industries. Approximately 53% of the inventors that depart from M&A firms are working at medium-high tech firms, while 38% of those belong to high tech industries. Comparatively to these two groups, the number of inventors composing our sample that work at M&A firms in either medium-low tech or low-tech is very small. The patenting profile of the M&A firms significantly differs between those for which inventors disappear from the database, over 3,100 patents in stock, those for which the inventors stay, 1,847 patents, and those for which inventors depart, 1,518 patents. This is over ten times the size of the patent stock of firms to which departing inventors go to.

Table 3-1. Descriptive statistics.

	Variables	Leave		Stay		Disappear		(A)	(B)
		Mean	SD	Mean	SD	Mean	SD	Diff.	Diff.
Inventor characterts.	Experience	5.11	4.34	5.38	5.13	3.76	4.85	-0.27*	1.61***
	Patent stock	4.81	7.01	3.64	6.05	2.31	3.60	1.17***	1.33***
	Citation st.	18.46	45.84	11.75	26.28	6.08	15.01	6.71***	5.66***
	Patent/Exp.	1.31	1.99	0.99	1.25	0.87	0.60	0.32***	0.12***
	Cit./Patent	3.16	5.30	3.09	5.51	2.56	5.24	0.07	0.53***
M&A firm characterts.	High tech	0.38	0.49	0.34	0.47	0.31	0.46	0.04***	0.03***
	Medium high tech	0.53	0.50	0.49	0.50	0.50	0.50	0.04***	-0.01
	Medium low tech	0.05	0.23	0.06	0.25	0.04	0.19	-0.01	0.03***
	Low tech	0.06	0.25	0.06	0.24	0.04	0.21	0.00	0.02***
	Patent stock	1518.22	2159.35	1847.09	1977.40	3198.64	4031.09	-328.87***	-1351.6***
New firm characterts.	Patent stock	141.35	289.47	-	-	-	-	-	-
Obs.		842		18,868		44,348		-	-

**** p<0.01, ** p<0.05, * p<0.1. Column (A) shows the difference between leave and stay; column (B) the difference between stay and disappear.*

Table 3-2 displays the patterns of mobility in terms of inventors' characteristics. Regarding the profile of inventors that disappear, the table suggests that inventors at early stages of their career or at very late stages of their career have the largest proportions of inventors disappearing, with a 69% and 58% respectively. For inventors with a low productivity, as measured with patents and citations, over 70% do not reappear in the dataset (meaning they are not actively patenting) after the M&A; this percentage decreases to about 50% for inventors with an average productivity and around 40% to inventors with an extremely high productivity. It is also interesting to note that the proportion of inventors that disappear decreases with inventors' patenting output except for the case of "star" inventors for which the percentage is slightly higher than the second most patent productive group of inventors.

As compared to the high percentage of inventors disappearing after the M&A (about two-thirds of the inventors), the proportion of inventors moving to a different firm is small with an overall rate of less than 4%. The table shows that inventors with 6 to 15 years of experience have the largest proportion of inventors moving to a different firm after the M&A, with mature inventors having the lowest rate of turnover. Regarding the output of inventors, the highest rates of mobility are observed among inventors with exceptional patent and citations stocks, with the turnover ratio being the lowest for low performing inventors.

Further, our data show that 56.7% of the inventors that move during the post-M&A period do so within the same industry and in the high tech (28.9%) and medium high tech (27.8%) sectors. This implies that 2.66% of the total number of inventors depart the M&A firms to a firm within the same industry. We also observed that about 20% of mobile inventors in the high-tech sector change industries within the high tech sectors and about 15% move from high tech industries to medium-low tech industries.

Table 3-2. Patterns of mobility.

Characteristics	Category	% Disappearing	% Departing (given non-disappear)
Experience (in years)			
	0-5 years	69.61%	3.61%
	6-10 years	54.57%	4.27%
	11-15 years	52.75%	4.31%
	>15 years	58.78%	1.99%
		(0.000)	(0.001)
Patent stock			
	0-2	72.09%	3.09%
	3-5	58.78%	3.81%
	6-15	47.96%	4.81%
	16-25	41.26%	6.81%
	>25	44.44%	8.50%
		(0.000)	(0.000)
Citation stock			
	0-2	73.70%	3.06%
	3-5	64.35%	3.60%
	6-15	57.90%	4.01%
	16-25	53.45%	4.37%
	26-35	50.53%	4.19%
	>35	42.40%	5.39%
		(0.000)	(0.000)
Total		65.86%	3.71%

Statistics in parentheses correspond to the p-values for the Pearson X^2 test of independence within categories.

As for the profile of the inventors moving, around 1% of mature inventors[25] move to firms with a lower patenting productivity, as compared to their M&A former employer, while 2.4% move to firms with the same

[25] Inventors with more than 10 years of experience; they represent about 18% of the sample of active inventors.

patent productivity profile. On the other end of the spectrum, inventors at early stages of their career (about 49% of mobile inventors), also move to firms with a similar patent productivity profile as their previous M&A employer but both within and across different industries (about 50% within the same industry). Top patenting inventors and inventors with above-average patent stock move mainly to firms with the same patent productivity as their M&A employer, with about a third of them switching industries. It is the inventors with the lowest patent stock that move to a firm with a lower patenting productivity, as compared to their M&As employers.

3.4.3 Who leaves after the M&A?

Table 3-3 presents the estimation results. We present two specifications (A and B), one basic specification that includes only inventor characteristics as explanatory variables for the mobility of inventors, and one specification that includes the level of technological intensity of the base M&A firm. Columns 2 and 4 show the determinants of the likelihood of an inventor to disappear from the database on the period after the M&A (selection equation). The exclusion restriction is the number of inventor names; the likelihood of an inventor disappearing from the database after the M&A event decreases with inventors' number of names; a larger number of names provides a unique identity to inventors and facilitates the process of names' disambiguation and the tracking of the inventor over different firms (Ge et al., 2016; Li et al., 2014).

It is important to note that given the high correlation between[26] patent and citation measures, we set up a cascade specification, to avoid problems derived from multicollinearity. Hence, experience, the ratio of patents to experience, and the ratio of citations to patents are included as explanatory variables in our model.

Individuals' characteristics do also have an impact on the likelihood of disappearing from the database. Experience has a nonlinear effect on the probability of disappearing. In particular, it displays a diminishing negative effect on the likelihood of disappearing. Inventors with lower experience and at earlier stages of their career are more likely to change the type of job (Topel and Ward, 1992), thus possibly continuing their career at a non-patenting firm, explaining the disappearance from the database. We also find a negative effect of patent productivity on the likelihood of disappearing; this could be due to the fact that taking advantage of the organizational changes and restructuring that takes place around the M&A, firms improve the match between employee and employer by dismissing those inventors that provide a lower performance, who then might not continue a patenting career (Siegel and Simons, 2010). A similar explanation can be applied to the negative effect of the citation-patent ratio on the likelihood to disappear.

Columns (1) and (3) show the predictors for inventor mobility (outcome equation). In both specifications, we find the effect of experience and patent-experience ratio on the likelihood to depart the M&A firm to be non-linear with a diminishing positive effect. The coefficients for these two variables suggest an inverted-U shape relationship. However, when we

[26] The correlation between patent stock and citation stock is 63.62% for the whole sample, 68.78% for the non-disappearing subsample, and 79.07% for the departing inventors subsample.

compute the turning points for the three variables, these are located around the 95% percentile of the distribution, so that for only a few observations from our sample the explanatory variables negatively affect the likelihood of departing. Patent-experience and citation-patent ratios, both indicators of the productivity or quality of the inventors, have a positive impact in the likelihood of departure, meaning that better performing inventors are more likely to depart the M&A firm. More productive inventors represent valuable assets for firms (Mawdsley and Somaya, 2016) and thus will receive more attractive job offers from outside firms (Hoisl, 2007; Palomeras and Melero, 2010). This is in line with previous M&A literature that finds that after an M&A, key inventors, who can easily find a new job, leave in search of a safer work environment (Ernst and Vitt, 2000; Gold, 1987; Miller, 1990; Olson, 1990; Roberts and Mizouchi, 1989). We also find that industry non-compete agreements significantly contributes to the disappearance of inventors in the post-M&A period. Finally, the year in which the M&A takes place influences the probability of inventor's mobility and disappearance, as the X^2-test on joint significance indicates.[27]

Regarding the adequacy of the model, the bottom of Table 3-3 displays the correlation coefficients between the error terms of selection and outcome equation (rho) as well as the likelihood ratio test of independence, which indicates that the outcome and selection equation can be independently estimated. Columns (1) and (2) in Table A3 (in the Appendix) include the estimation of ordinary probit models, i.e. without including the selectivity of inventors' disappearance in the estimation of

[27] The X^2 statistic for the joint significance of the year dummies is 5600.15, significant at a 1%.

the outcome equation; it confirms largely our previous findings by displaying the signs and significance of the coefficients on Table 3-3.

Table 3-3. Estimation results for the probability of departing (Heckman selection model).

	(A)		(B)	
	(1)	(2)	(3)	(4)
VARIABLES	Departure	Non-disappear	Departure	Non-disappear
Experience	0.074**	0.203***	0.064**	0.203***
	(0.031)	(0.003)	(0.032)	(0.003)
(Exp)^2	-0.003***	-0.007***	-0.003**	-0.007***
	(0.001)	(0.000)	(0.001)	(0.000)
Patents/Exp	0.205***	0.255***	0.194***	0.256***
	(0.039)	(0.015)	(0.042)	(0.015)
(Patents/Exp)^2	-0.005***	0.002	-0.005***	0.002
	(0.001)	(0.003)	(0.001)	(0.003)
Citations/Patents	0.013**	0.008***	0.012*	0.008***
	(0.006)	(0.002)	(0.006)	(0.002)
(Citations/Patents)^2	-0.000	-0.000***	-0.000	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Ind. non-compete	0.041	-0.048***	0.060	-0.051***
	(0.050)	(0.014)	(0.051)	(0.014)
High tech			0.089**	0.019
			(0.042)	(0.014)
Medium-high tech			0.138***	0.003
			(0.044)	(0.014)
Medium-low tech			-0.315***	0.134***
			(0.089)	(0.028)
Number of names		0.065***		0.064***
		(0.010)		(0.010)
Observations	66,671	66,671	66,671	66,671
Year dummies	YES	YES	YES	YES
Log likelihood	-40138.322	-40138.322	-40104.650	-40104.650
Model chi-square	782.847	782.847	786.907	786.907
Prob > chi2	0.000	0.000	0.000	0.000
Rho	0.186	0.186	0.095	0.095
LR test of indep	0.494	0.494	0.713	0.713

*Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1*

3.4.4 Where do they go to?

Table 3-4 and Table 3-5 present the estimation results for the mobility direction of departing inventors. As in Table 3-3, we present two specifications (A and B), one including only inventor characteristics and one specification including as well the level of technological intensity of the base M&A firm. Each of the specifications includes three columns, each of them representing one stage in the three-stage Heckman selection model. As in Table 3-3, the first and second stage are the probability of inventors non-disappearing and departing the M&A firm, and the third stage, which depends on the other two recursive selection equations, is the probability of the inventor moving to a firm in the same industry (Table 3-4) or to a firm with lower technological leadership (Table 3-5).

The different specifications confirm the findings from the previous section. For these specifications, we include the proportion of inventors that leave the M&A firm at the same time as the inventor of interest as exclusion restriction. As in Table 3-3, the likelihood ratio test of independence does not support the significance of the correlations between the outcomes and selection equations, so that independent probits can be estimated (see columns (3) to (5) on Table A3 in the Appendix).

Table 3-4 suggest that the mobility of inventors to firms in the same industry is independent of inventors' characteristics. Surprisingly, it also shows that compete agreements do not exercise any effect on whether inventors leaving a merging firm move to the same industry or not. Inventors in high-tech industries are more likely to stay within the same industry, while inventors in medium-low tech industries are less likely to remain in the same industry.

Table 3-4. Estimation results for the probability of moving to a firm in the same industry (Three-stage Heckman selection model).

	(A)			(B)		
VARIABLES	(1) Same industry	(2) Departure	(3) Non-disappear	(4) Same industry	(5) Departure	(6) Non-disappear
Experience	0.067	0.080***	0.203***	-0.035	0.087***	0.203***
	(0.076)	(0.028)	(0.003)	(0.043)	(0.027)	(0.003)
(Exp)^2	-0.003	-0.003***	-0.007***	0.001	-0.004***	-0.007***
	(0.003)	(0.001)	(0.000)	(0.002)	(0.001)	(0.000)
Patents/Exp	0.023	0.209***	0.255***	-0.116*	0.218***	0.253***
	(0.124)	(0.034)	(0.015)	(0.059)	(0.032)	(0.015)
(Pat./Exp)^2	-0.004	-0.005***	0.002	0.001	-0.005***	0.002
	(0.006)	(0.001)	(0.003)	(0.003)	(0.001)	(0.003)
Cit./Patents	-0.003	0.016***	0.008***	-0.016	0.015**	0.008***
	(0.035)	(0.006)	(0.002)	(0.032)	(0.006)	(0.002)
(Cit./Patents)^2	-0.002	-0.000*	-0.000***	-0.001	-0.000	-0.000***
	(0.002)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Ind. non-compete	-0.135	-0.009	-0.048***	0.022	0.007	-0.051***
	(0.148)	(0.057)	(0.014)	(0.145)	(0.058)	(0.014)
High tech				0.630***	0.108**	0.019
				(0.126)	(0.045)	(0.014)
Medium-high tech				0.166	0.132***	0.003
				(0.138)	(0.048)	(0.014)
Medium-low tech				-0.484*	-0.153	0.134***
				(0.250)	(0.096)	(0.028)
Number of names			0.064***			0.063***
			(0.010)			(0.010)
Leaving inventors %		2.863***			2.825***	
		(0.260)			(0.272)	
Observations	842	18,184	66,671	842	18,184	66,671
Year dummies	YES	YES	YES	YES	YES	YES
Log likelihood	-40116.467	-40116.467	-40116.467	-40068.132	-40068.132	-40068.132
Model chi-square	12494.243	12494.243	12494.243	12590.914	12590.914	12590.914
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000
Rho	0.269^{α}	-0.326^{β}	-0.123^{γ}	0.341^{α}	-0.741^{β}	-0.236^{γ}
LR test of indep.	0.320	0.644	0.437	0.238	0.109	0.058

*Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1*
α: rho of 2nd with 3rd stage; β: rho of 1st with 3rd stage; γ rho of 1st with 2nd stage.

Table 3-5. Estimation results for the probability of moving to a firm in a lower technological leadership group (Three-stage Heckman selection model).

	(A)			(B)		
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Lower Tech Leadership	Departure	Non-disappear	Lower Tech Leadership	Departure	Non-disappear
Experience	-0.139*	0.087***	0.203***	-0.134*	0.075**	0.203***
	(0.072)	(0.029)	(0.003)	(0.079)	(0.031)	(0.003)
(Exp)^2	0.006*	-0.004***	-0.007***	0.005	-0.003***	-0.007***
	(0.003)	(0.001)	(0.000)	(0.003)	(0.001)	(0.000)
Patents/Exp	-0.473***	0.217***	0.254***	-0.475***	0.205***	0.255***
	(0.106)	(0.035)	(0.015)	(0.118)	(0.038)	(0.015)
(Pat./Exp)^2	0.012**	-0.005***	0.002	0.012**	-0.005***	0.002
	(0.005)	(0.001)	(0.003)	(0.005)	(0.001)	(0.003)
Cit./Patents	0.018	0.016***	0.008***	0.018	0.015**	0.008***
	(0.022)	(0.006)	(0.002)	(0.023)	(0.006)	(0.002)
(Cit./Patents)^2	0.000	-0.000*	-0.000***	0.000	-0.000	-0.000***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Ind. non-	0.016	-0.008	-0.048***	0.091	0.009	-0.051***
compete	(0.171)	(0.057)	(0.014)	(0.187)	(0.059)	(0.014)
High tech				0.139	0.108**	0.019
				(0.152)	(0.045)	(0.014)
Medium-high tech				-0.115	0.135***	0.003
				(0.161)	(0.049)	(0.014)
Medium-low tech				-0.089	-0.169*	0.134***
				(0.271)	(0.098)	(0.028)
Number of names			0.064***			0.063***
			(0.010)			(0.010)
Leaving inventors %		2.791***			2.841***	
		(0.282)			(0.262)	
Observations	842	18,184	66,671	842	18,184	66,671
Year dummies	YES	YES	YES	YES	YES	YES
Log likelihood	-40021.173	-40021.173	-40021.173	-39995.536	-39995.536	-39995.536
Model chi-square	12561.068	12561.068	12561.068	12612.344	12612.344	12612.344
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000
Rho	0.345^{α}	-0.301^{β}	-0.074^{γ}	0.225^{α}	-0.197^{β}	-0.025^{γ}
LR test of indep.	0.294	0.680	0.689	0.431	0.772	0.862

*Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1*
α: rho of 2nd with 3rd stage; β: rho of 1st with 3rd stage; γ rho of 1st with 2nd stage.

Table 3-5 explore whether inventors move to firms that have a lower patenting output (relative to other firms in the same industry) as compared to the M&A firm or instead they have the same patent productivity profile. The results provide different insides into the patterns of mobility. First, we find that as inventor's experience increases, up to a maximum of 19.8 years, inventors' likelihood of moving to a firm with lower patent productivity decreases while the likelihood of moving to a firm with same patent productivity increases (see Table A2 in the Appendix[28]). However, for inventors for an experience of over 11.6 years, about the upper 10 percentile of the sample, as experience increases, they are more likely to move to a firm with a lower patent productivity, while their likelihood of moving to a firm with the same patent productivity decreases. Second, the results show that inventors with a higher patent productivity are more likely to move to a firm with the same patenting level as the M&A firm, while inventors that are less productive are more likely to move to a firm with lower patent productivity. This pattern reflects the job matching process by which inventors move to jobs that better fit with their quality (Hoisl, 2007; 2009; Topel and Ward, 1992). This is true for about 99% of the inventors, as only the upper 1%, i.e. inventors with over 19.8 years of experience, tend to move to firms with a lower technological leadership. Our results also suggest that the destination of mobile inventors is independent from the industry in which they are based and on the existence of non-compete agreements. On the other hand, year dummies significantly affect inventors' likelihood of moving to a firm

[28] We created three categories: lower tech leadership, same tech leadership and higher tech leadership. However, out of the 842 mobile inventors only one moved to a firm with a higher technological leadership (645 to a firm with the same technological leadership and 196 with a lower technological leadership).This basically implies that "lower tech leadership" and "same tech leadership" will have very similar coefficients but with opposite signs. The results for "same tech leadership" are displayed in Table A2 in the Appendix.

with certain characteristics as supported by the X^2-test on joint significance.[29]

Finally, for both Table 3-4 and Table 3-5, the results also show that a higher proportion of inventors departing the M&A firm positively influences the individual inventor's likelihood of departure. A higher proportion of inventors' departure may signal restructuring activities, which are often found to provoke higher fluctuations of personnel either through firms' deliberate dismissal or through the voluntary departure of inventors who do not agree with the changes brought by the M&A (Ernst and Vitt, 2000; Walsh, 1988).

3.5 CONCLUSIONS

Previous literature on M&As as well as competition authorities have highlighted the potential negative consequences of M&As for the innovation activities of merging parties, as well as the derived negative impact on society's welfare (e.g. Arrow, 1962). The argument is that an increase in market concentration lowers the incentives to innovate for the merging firm. This paper explores whether M&As facilitate the diffusion of knowledge through the post-M&A departure of inventors. The diffusion of M&A firms' knowledge to other firms -with a potentially weaker technological profile- may have a pro-competitive effect as this external knowledge may be recombined and used to generate new innovations at the inventors' new employers (Rosenkopf and Almeida, 2003). This paper profiles inventors and firms to determine the extent to which M&As facilitate knowledge diffusion.

[29] The X^2 statistic for the joint significance of the year dummies is 2347.18, significant at a 1%.

Our results show that about 4% of the inventors leave around the M&A. We find that inventors' experience and patent productivity are conductive of mobility, particularly to firms within the same patenting profile. To a lesser extent, we also observe mobility across industries and to firms with lower patenting profiles, very much facilitated by non-compete agreements.

While limiting the scope of knowledge diffusion, the fact that mobility of inventors occur in its majority between firms in the same technological profile (either same industry, technological intensity or patenting productivity) ensures that recipient firms possess the sufficient absorptive capacity to assimilate the knowledge brought by the inventors departing the M&A firms (Cohen and Levinthal, 1990). This suggests that part of the knowledge held by M&A parties is not lost with the restructuring activities but rather transfer to third non-M&A firms with a similar technological profile. This transferred of technology observed previously is in line with U.S. competition policy regulations that impose divestitures as a relief for the potential anti-competitive effects of M&As on innovation.

Our work is not free of limitations. First, as with the majority of inventor mobility studies, this paper detects the instances of mobility with patent data (e.g. Almeida and Kogut, 1999; Singh and Agrawal, 2011). This means that mobility can only be identified when the inventor has at least successfully patented twice, once before and once after moving, and when inventor's employer chooses to patent over secrecy (Cohen et al., 2000; Png, 2015). Second, our dataset impedes us to identify the reasons behind inventors' departure, so that we cannot distinguish between voluntary or involuntary departure. Moreover, since our dataset is restricted to firms engaging in M&A activities, we cannot compare the mobility rates triggered by M&As to the mobility rates in the absence of M&As. Thus, it might be interesting, for future research, to explore this question.

CHAPTER 4

PATENT EXPIRATION AS AN ACQUISITION MOTIVE IN THE PHARMACEUTICAL INDUSTRY

4.1 INTRODUCTION

Prior literature points out that patents as indicators of the technological value of firms' knowledge base with rare, valuable, inimitable and non-substitutable characteristics provide firms' with the basis for achieving a competitive advantage (Adegbesan and Higgins, 2010; Ahuja and Katila, 2001; Henderson and Cockburn, 1994; Markman et al., 2004). Patents are particularly important in the pharmaceutical industry, as they endow pharma firms with competitive advantages through exclusionary rights (Yang and Maskus, 2000), legal monopolies and legal barriers for substitution that translate into superior performance (Markman et al., 2004). Patents behind successful drugs are responsible for high levels of revenue, which are quickly captured by generic substitutes when these patents expire (Barret et al., 1999; Gambardella, 1992; Ravenscraft and Long, 2000)[30].

The fact that patents' life is limited to a maximum of 20 years implies that to maintain high levels of profitability over time, pharmaceutical firms need to constantly develop or acquire new patents to substitute those which are expiring. The problem of patent life length is of particular relevance in the pharmaceutical industry, where the lag between patent filing, at the time of invention, and commercialization reduces the effective time of patent protection to half (Budish et al., 2015; 2016). In this context, externally sourcing of technology is especially attractive in the pharmaceutical industry, where the process of drug discovery and patent generation takes considerable risk, time and investment (DiMasi, 2001; LaMattina, 2011; Rothaermel and Hess, 2007).

Acquisitions represent a possible strategy for pharmaceutical firms to overcome the lack of biotechnological knowledge, reduce R&D costs, increase the number of potential products in their pipelines, close earning gaps and fill the gaps in the patent portfolio (Ahuja and Katila, 2001; Ranft and Lord, 2002). From the innovation point of view, the loss of strategically key innovation resources pushes firms to undertake acquisitions to fill the gaps in firms' product pipelines left by the expiring patents (Comanor and Scherer, 2013; Danzon et al., 2007; Grabowski and Kyle, 2008; Higgins and Rodriguez, 2006; Rafols et al.,2014). In particular, given that pharmaceutical patents' development entails tacit knowledge and is surrounded by uncertainty, several authors indicate that managers' best strategy may be the acquisition of the firm possessing the

[30] For example, the expiration in 2011 of the patent behind the anti-cholesterol drug Lipitor, one of the top selling drugs of Pfizer, responsible for over 16% of the firms' total revenue, left a sales gap of over $10 billion (Kenley, 2011).

technology; this strategy avoids excessive transaction costs and permits the full internalization of the acquired technologies (Leonard-Barton, 1995; Schilling and Steensma, 2002).

However, despite the importance of acquisitions as a strategy to fill the gaps left by expiring patents, the number of studies exploring the motivations behind firms' acquisition decisions is little (Andrade et al., 2001; Higgins and Rodriguez, 2006) as compared to the vast number of studies on the consequences of acquisitions on firms' performance (e.g. Ahuja and Katila, 2001; Cassiman et al., 2005; Cloodt et al., 2006; King et al., 2004). This is surprising, given the multiple calls for an adequate empirical research on acquisitions that deepens on the motives, industry sector and firm characteristics to understand the performance outcomes of acquisitions and the high failure rates (Pablo and Javidan, 2004; Schweizer, 2005; Sirower, 1997). These studies indicate that to understand acquisitions, and thus be able to provide adequate recommendations and strategies to ensure acquisitions' success, researchers need to first explore and identify the motives underlying acquisitions decisions (Bower, 2001: Javidan et al., 2004; Schweizer, 2005; Shrivastava, 1986). Previous literature on acquisition motives has failed to satisfy this by orienting their research towards the generation of taxonomies and lists outlining the different motives for acquisition without exploring the mechanism and channels behind these motives. This paper aims at filling this gap by exploring one possible mechanism, from the resource-based view (RBV) perspective, and answering the following research question: what is the impact of patent expiration on firms' acquisition decision and how does innovative capability moderate this effect?

Patent expiration has been acknowledged by previous financial economics and industrial organization literature as a mechanism driving firms' acquisition decision (e.g. Higgins and Rodriguez, 2006 or Danzon et al., 2007). Building on their findings, this paper provides a comprehensive framework in which the role of patents as sources of competitive advantage and as determinants of firms' strategy is highlighted, and in which the interplay between firms' innovation resources and capabilities in determining firms' acquisition strategy is considered. To my knowledge, this is the first study in the RBV literature that explores the motives behind firms' acquisitions decisions by taking into account the joint action of innovative resources and capabilities on firms' strategic decision process. This is an important question in the RBV literature as both critical resources and capabilities are contributing factors to a firm's strategy (Grant, 1991).

While acknowledging that acquisitions are driven by a complex pattern of motives (Bower, 2001; Schweizer, 2005; Steiner, 1975; Trautwein, 1990), this paper focuses on innovation motives for various reasons. First of all, as compared to financial and economic motives, innovation motives have only been recently explored (e.g. Ahuja and Katila, 2001; Bower, 2001), with a large body of the research devoted to the study of acquisition effects on innovation, leaving room for new research that aims at understanding the innovation mechanisms behind acquisitions decisions. Second, a holistic and all-inclusive analysis of the acquisition motives will prevent an in-depth study and will follow the path of previous studies that while broad, provide a superficial treatment of the motives, failing to address the calls for a more exhaustive study.

Using a sample of U.S. pharmaceutical firms for the period 1985-2010, the results show that indeed patent expiration is a triggering factor of firms' acquisitions decision, which is explained by the short-term necessity of firms to fill the pipeline gaps left by expiring patents and to maintain revenue streams. The results also show that this effect is negatively moderated by firms' innovative capability, which endows firms with a higher capacity to internally generate new innovations, thus reducing the external dependency.

This study contributes to the current literature in several ways. First, it adds to the RBV by highlighting a mechanism through which firms' resources affect firms' strategic decisions. Second, it stresses the importance of innovation as a resource and as a capability on firms' acquisitions decision-making process. Third, it provides practitioners and acquisitions scholars with a useful indicator, alternative to the existing financial-based indicators that anticipates acquisitions' decision. Finally, from the empirical point of view, it uses a novel tailor-made database that links pharmaceutical firms' financial data with acquisition information and innovation data, including patents and publications. The use of publications as a proxy for basic research is also new on acquisitions empirical literature and it can be useful in the study of technologically related acquisitions[31].

[31] Basic research conceptualized as publications has mainly been used in literature dealing with firms' innovation productivity and knowledge generation (e.g.: Cardinal and Hatfield, 2000; Cockburn and Henderson, 1998; Fabrizio, 2009; Gambardella, 1992; Lim, 2004).

Chapter 4

4.2 THEORETICAL BACKGROUND

4.2.1 Previous literature on the motives of M&As[32]

M&As have been investigated by scholars from several disciplines, and through various theoretical lenses to generate a broad body of literature that has investigated a wide range of questions ranging from M&As' motives, M&As' creation of value, M&As' effect on performance, to post-M&A integration (Schweizer, 2005). As compared to the vast literature on M&As consequences, M&As motives have triggered far less theoretical and empirical contributions, with the majority of the discussions serving as preambles to the study of M&As consequences or as a base to provide prescriptions to the execution of M&As. In this sense, very few papers have provided an exhaustive analysis of M&As motives, with their efforts directed towards the generation of taxonomies distinguishing the different motivations for M&As. Two of the major references in this strand of literature are Trautwein (1990) and Walter and Barney (1990). These two studies report that firms' engage in M&As to obtain market power, to increase the market share, to access market synergies, to achieve a greater efficiency, or economies of scale, to enlarge their product line or complement their products or services, as a means for diversification, to spread the risk; to share resources, and to expand geographically (see Table 4-1).

[32] This paper focuses on acquisitions; however, this section provides a more ample literature review including both mergers and acquisitions since many of the papers included here refer to both.

Table 4-1. Literature review on acquisition motives.

Obtain market power	Ellert (1976), Goldberg (1983), Pennings et al. (1994), Ravenscraft and Scherer (1987), Steiner (1975), Trautwein (1990)
Access market synergies	Campbell and Goold (1998), Carpenter and Sanders (2007), Mandelker (1974), Porter (1985), Seth et al. (2000, 2002), Townsend (1968)
Achieve greater efficiency	Bower (2001), Eckbo (1986), Steiner (1990), Trautwein (1990)
Achieve economies of scale	Bower (2001), Goldberg (1983), Ravenscraft and Scherer (1987), Steiner (1975)
Enlarge or complement product/service line	Levinson (1970)
Diversification	Larsson and Finkelstein (1999), Steiner (1990), Trautwein (1990), Walter and Barney (1990)
Spread risk	Pennings et al. (1994), Trautwein (1990)
Share resources	Steiner (1990), Trautwein (1990)
Expand geographically	Bower (2001), Steiner (1990), Trautwein (1990)
Access to R&D skills, technical expertise, knowledge and technologies	Bower (2001), Ruckman (2005)

More recent research also highlights that current trends in acquisitions seek to access R&D skills, technical expertise, knowledge, and technologies from the target (Bower, 2001; Ruckman, 2005). Some of these studies understand M&As as a substitute for in-house R&D, and point to managers' desire to obtain valuable resources, including know-how, technologies, and capabilities possessed by the target firms as a motive (Ahuja and Katila, 2001; Chaudhuri and Tabrizi, 1999; Inkpen, Sundaram and Rockwood, 2000; Schweizer, 2005).

Despite providing a comprehensive list of motives for acquisitions, these studies have failed to address the call from previous literature of the need to deepen in the motives of M&As in order to better understand the performance effects of M&As and the reasons for the high failure rate of M&As (Bower, 2001; Pablo and Javidan, 2004; Ranft and Lord, 2002; Rabier, 2017; Schweizer, 2005).

This paper tackles this gap in the literature by disentangling one possible channel, the loss of competitive advantage that motivates firms' acquisition decision. In particular, it examines the case of patent expiration as an antecedent of pharmaceutical firms' decision to acquire another firm. The choice of patent expiration as a driving mechanism is rooted in previous studies in industrial organization and financial economics literature that have acknowledged the role of patent expiration on firms' M&As decisions. On its side, industrial organization literature points out that in the pharmaceutical and biotech industries patent expirations generate gaps on firms' product pipelines that make firms' current levels of physical and human capital excessive, motivating firms' capacity adjustment through M&As (Danzon et al., 2007). On the other hand, financial economics understands patent expiration as an example of the internal inefficiencies in the pharmaceutical industry. Higgins and Rodriguez (2006) examine the state of firms' internal productivity, by considering, among other factors, expected years of patent life to find that indeed higher patent expiration is conductive of M&As activity. These results are also confirmed on a broader set up of 48 different industries by Zhao (2009).

4.2.2 Patents as a source of competitive advantage in the pharmaceutical industry

This paper builds on the RBV of the firm, and specifically, on Grant's (1991) work which emphasizes the role of firms' resources and capabilities as foundations for firms' strategies. Firms' internal resources and capabilities provide the basic direction for firms' strategy, and represent the primary source of firms' profitability, through the attainment of competitive advantages (Grant, 1991). Barney (1991) points out that the heterogeneous distribution and imperfect mobility of resources and capabilities across firms grant them with the possibility of obtaining a competitive advantage over their competitors. In this sense, RBV literature highlights that resources that are rare and valuable enable firms to achieve a higher performance (Amit and Schoemaker, 1993; Barney, 1991; Powell, 2001). Moreover, if these resources are non-substitutable, inimitable, appropriable, durable and superior this competitive advantage would be sustained over time (Amit and Schoemaker, 1993; Barney, 1991; Collis and Montgomery, 1995; Powell, 2001). Hence, firms' capacity to secure difficult-to-imitate and difficult-to-substitute resources is the key to generating monopolistic rents and superior performance (Autio, Sapienza & Almeida, 2000; Markman et al., 2004)

Attending to these characteristics, several studies have pointed out that patents, as intangible resources and indicators for firms' inventive capacity, provide pharmaceutical firms' with the basis for obtaining a sustainable competitive advantage (Henderson and Cockburn, 1994; Markman, Espina and Phan, 2004). This is because patents grant protection for up to 20 years, are legally associated with the firm and, compared to other IP protection mechanisms, they offer greater protection (Newbert, 2008). This protection implies that patents provide firms with technology-based first mover advantage (Markman et al., 2004) and prevent rivals from using the patented invention without permission, which further strengths the first-mover advantage (Rivette and Kline, 2000). Given the importance of patents as a source of competitive advantage and to secure the benefits derived from patented inventions, pharmaceutical firms often incur in high legal costs to first obtain and then maintain ownership of patent rights and to fight any patent infringements (Markman et al., 2004; Rivette and Kline, 2000).

Apart from providing firms with exclusive rights, patents facilitate the establishment of agreements with other firms. Nelson and Winter (1982) pose that as compared to other sources of competitive advantage, patents are particularly valuable in the establishment of inter-firm agreements because they are easily transferred and highly portable. These two characteristics provide the core for setting up joint ventures and cross-licensing deals based on intellectual property rights and they provide the basis of technology licensing agreements, which generate cash flows for the owner of the patent (Markman et al., 2004).

Relative to other industries, patents, as a source of competitive advantage and superior performance, are particularly important in the pharmaceutical industry. Patents endow pharma firms with competitive advantages through exclusionary rights (Yang and Maskus, 2000), legal monopolies and legal barriers for substitution that translate into superior performance both in new products and revenue streams (Markman et al., 2004). Moreover, several studies find that patents are the most important mechanism for IP appropriation in the pharmaceutical industry (Levin et al., 1987) as patents are the most effective and the most often used IP mechanism for both product and process invention, where approximately 80% of the patentable inventions are patented as compared to other industries in which this rate is 60% (Arundel, van de Paal and Soete, 1995; Arundel, 2000; Cohen, Nelson and Walsh, 2000; Hussinger, 2006; Mansfield, 1986).

The potential benefits derived from protection do not come without a cost; the process of discovery and development of new chemical entities entails significant amounts of R&D expenditures and high uncertainty (Frantz, 2006). First of all, it takes an average of 10 years for a new drug to complete all the phases from initial discovery to its launch into the market with an estimated cost of $2.6 billion[33] (PhRMA, 2015). Moreover, the probability that a drug will be eventually approved by the FDA so that it could be launched into the market, is less than 12% (PhRMA, 2015). This means that because only a few products make it to the market and the high cost of launching a new drug, stakes in the pharmaceutical industry are particularly high, as firms unable to secure their products by patents are severely punished in the marketplace and unable to recover their R&D investments (Cool et al. 1999; Markman et al., 2004). This is why after the discovery phase, pharmaceutical firms race to file patent applications at the USPTO to protect the potential value of their discovery (Daizadeh et al., 2002).

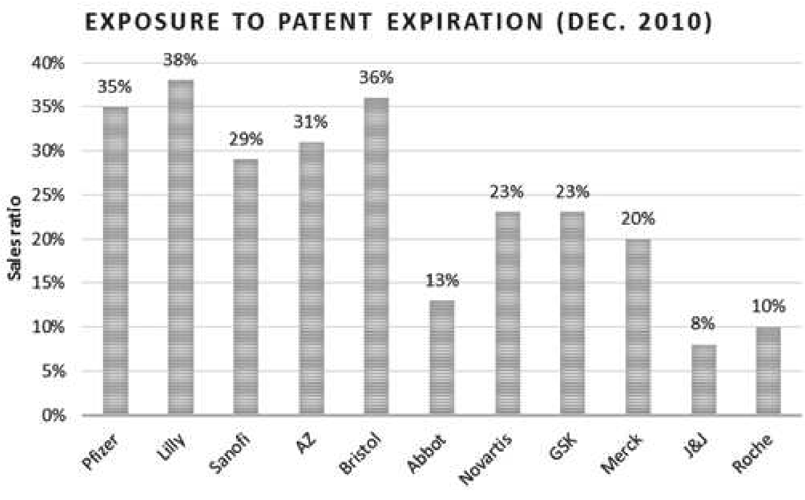
[33] This figure incorporates the cost of failures, i.e. compounds that at the end do not receive the approval to be launched into the market.

4.3 HYPOTHESES

4.3.1 Patent expiration as a motive for firms' acquisitions

The reliance of pharmaceutical firms on patents as a source of profitability and superior performance is apparent on the gap left on firms' revenue streams when the patent protection expires (Barret, Licking and Kerry, 1999; Gambardella, 1992; Ravenscraft and Long, 2000). Barret et al. (1999) report that strong patents are able to capture large amounts of value as firms can lose up to 80% of its revenue income to generic substitutes when these patents expire. For example, in 2010, big pharma companies such as Pfizer, Bristol or Lilly had over 30% of their sales coming from drugs whose patents were about to expire (Kenley, 2011) (see Figure 4-1); while between 2006-2011 patent expiration of top-selling drugs generated revenue loses over $50 billion (Frantz, 2011) (see Table 4-2).

Figure 4-1. Exposure to patent expiration.



Source: Kenley (2011)

Table 4-2. Exposure to patent expiration.

Drug	Company	2010 Sales	Expiration year
Lipitor	Pfizer	$10.7 billion	2011
Remicaide	Johnson & Johnson	$7.3 billion	2011
Plavix	Sanofi	$6.7 billion	2012
Singulair	Merck	$ 5.0 billion	2012

Source: Kenley (2011)

Given the importance of patents for pharmaceutical firms' performance, and in line with Grant's theoretical framework that firms adapt and build their strategy around critically important resources (Grant, 1991), it is not surprising that pharmaceutical firms' strategies are substantially influenced by changes in the patent portfolio of the firm, and in particular by patent expiration.

The importance of patents to maintain high levels of profitability over time translates into a continuous need to develop new patents that fill the gaps left by expiring patents (Kenley, 2011). When it comes to technology development, large innovative firms can decide between internal developing strategies or external sourcing strategies (Cassiman and Veugelers, 2006; Rigby and Zook, 2002). Firms may decide for an external technology sourcing strategy when they lack the capabilities to develop the technologies on their own or, as in the case of the pharmaceutical industry, when the process of drug discovery and patent generation takes considerable time and investment (Cassiman and Veugelers, 2006; DiMasi, 2001). In particular, firms can enter into a technology sourcing agreement with an outside party, e.g. R&D outsourcing, licensing, joint ventures, company acquisitions or hiring of qualified researchers, to jointly develop or to buy an already developed technology (Arora and Gambardella, 1990; Cockburn and Henderson, 1998; Lambe and Speakman, 1997).

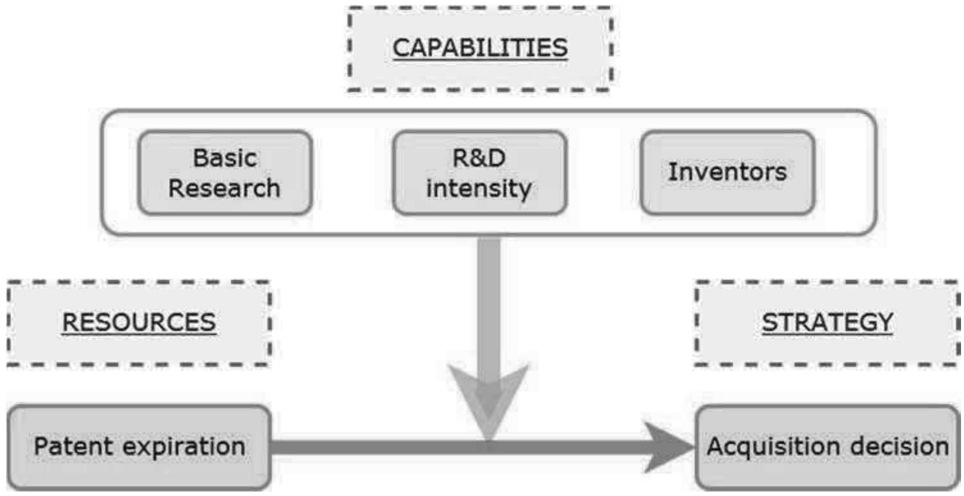
Schilling and Steensma (2002) point out that given that pharmaceutical patents, as sources of competitive advantage, are specific, entail tacit knowledge and are surrounded by uncertainty, the best external sourcing strategy is the acquisition of the firm possessing the technology. This is because acquisitions grant the acquiring firm the possibility of applying control over the assets, human capital and technologies of the acquired firm, such as the patents portfolio, and use them in a way that satisfy its current needs (Folta, 1998; Schilling and Steensma, 2002), providing a greater potential for development of core technological capabilities and exploitation of competitive advantages (Leonard-Barton, 1995). Several contributions have also acknowledged the important role of acquisitions when the firm is in need of external sources of innovation (Arora and Gambardella, 1990; Haspeslagh and Jeminson, 1991; Hitt et al., 1996; Pisano, 1991); for example, Hagedoorn and Duysters (2002) empirically support that acquisitions are preferred to strategic alliances as an external sources of innovation for the core units. Thus, the following hypothesis is derived:

Hypothesis 1: Patent expiration positively influences firms' decisions to engage in horizontal acquisitions.

4.3.2 The moderating role of innovative capability

Taking as a departure point the findings from studies in industrial organization and financial economics, this study contributes to the management literature, and specifically to the RBV of the firm, by considering how patents, as key resources of pharmaceutical firms, influence the acquisition decision given firms' innovative capability. The inclusion of innovative capability into the analysis is novel in the literature on the motives of acquisitions, and it is important as resources and capabilities act together in providing and sustaining firms' competitive advantage (Amit and Schoemaker, 1993; Barney, 1991; Powell, 2001; Guan and Ma, 2003) and in determining firms' strategy (Grant, 1991) (see Figure 4-2). Evaluating the relevance of resources and capabilities enables a better understanding of firms' (acquisition) strategies.

Figure 4-2. Conceptual model



This paper focuses its analysis on innovative capability; from a RBV, several authors highlight that innovative capability, as compared to other capabilities, is crucial for firms' strategic competitiveness by creating sustained performance differences with other firms (Barney, 1991; Hagedoorn and Duysters, 2002; Nelson, 1991; Rumelt, 1984; Wernerfelt, 1995), particularly in high-tech industries such as the pharmaceutical

(Conner, 1991; Sher and Yang, 2005). Innovative capability "concerns the specific expertise and competence related to the development and introduction of new processes and products" (Hagedoorn and Duysters, 2002: p. 168). The innovative capability is related to the internal processes, organizational culture and the capacity of firms' to respond to changes in the environment (Akman and Yilmaz, 2008; Cohen and Levinthal, 1989; Hagedoorn and Duysters, 2002; Neely et al., 2001). This ability to properly respond to changes in the environment is fundamental to achieving success in the market because it allows the firm to adapt to the market, the environment and the competition (Elmquist and Le Masson, 2009; Guan and Ma, 2003; Martinez-Roman et al., 2011). Innovative capability rests on firms' capacity to generate and apply new knowledge, in the form of new ideas and concepts, to obtain market value and to take advantage of market opportunities (Assink, 2006; Calantone et al., 2002; Elmquist and Le Masson, 2009; Zhao et al., 2005).

Thus, innovative capability depends upon the knowledge possessed by the firms that permits the generation of new technologies, or the improvement of existing ones (Romijn and Albadalejo, 2002; Wonglimpiyarat, 2010), and provide the basis for the development of new technologies and patents (Chen and Yang, 2009; Martinez-Roman et al., 2011; Puranam et al., 2000). Likewise, the internal efforts, as an input of innovative capability, oriented to achieve knowledge and technological innovations are also an important determinant of the level of innovative capability (Elmquist and Le Masson, 2009; Kroll and Schiller, 2010; Martinez-Roman et al., 2011).

Previous authors have highlighted the complexity and multidimensionality of innovative capability (see Martinez-Roman et al., 2011, for a review), characterizing innovative capability with diverse factors such as external sources of knowledge (Cohen and Levinthal, 1990; Damanpour, 1991; Feldman, 1995), learning and capacitation (Bertrand, 2009; Damanpour, 1991), R&D (Furman et al, 2002; Puranam et al., 2009; Quintana and Benavides, 2008; Subramaniam and Youndt, 2005) or staff training and attitude (Damanpour, 1991; Nassimbeni, 2001; Pearce, 1993). Since the paper is interested in the analysis of the moderating effect of innovative capability, I only focus on the specific factors that permit firms' transformation of knowledge into patents. Thus, I proxy innovative capability with R&D efforts, knowledge and human capital (see e.g. Baden-Fuller and Pitt, 1996; Nueno, 1998).

First of all, R&D efforts, conceptualized as R&D expenditures, refers to firms' technological efforts (Sher and Yang, 2005). The discovery and development process of drugs is a long and complex process that requires the establishment of R&D labs, the hiring of scientific personnel and large investments in R&D (Cardinal and Hatfield, 2000). Previous studies have pointed out the importance of R&D expenditures in the generation of innovation and patents, finding a strong relationship between R&D expenditures and patenting output (e.g. Bound et al., 1984; Hausman et al., 1984; Jaffe, 1986; Pakes and Griliches, 1980; Hitt et al., 1997; Keizer et al., 2002). Second, regarding the knowledge underlying innovative capability, I consider firms' basic research base. Basic research is essential for the knowledge creation process of firms (Griliches, 1980; Tijssen, 2004), and it is key for internalizing, modifying and applying external knowledge (Cohen and Levinthal, 1990). Basic research provides firms with a technological landscape in which they can search for new innovations and guides them towards promising drugs in the drug discovery process (Drews, 200; Fleming and Sorenson, 2004). Finally, human capital understood as scientific personnel or inventors are sources of knowledge and talent that exploit and transform knowledge into patents (Cyert and March, 1983; Grant, 1996). Because of the knowledge, expertise and skills that inventors have gained through their education, training, and experimental learning (Becker, 1975; Coff, 2002; Hatch and Dyer, 2004), they develop tacit knowledge about specific technologies or inventions that is of high value to firms (Herstad et al., 2015; Mawdsley and Somaya, 2016) and that represents an important driver of firms' competitive advantage (Barney, 1991; Gardner, 2002). All of these factors should allow firms to more easily come up with patents and to reduce their dependency on external sources to replenish their patent portfolios. Thus, the following hypotheses are derived:

Hypothesis 2a: Innovative capability, measured as R&D efforts, negatively moderates the effect of patent expiration on firms' decision to engage in acquisitions.
Hypothesis 2b: Innovative capability, measured as basic research, negatively moderates the effect of patent expiration on firms' decision to engage in acquisitions.
Hypothesis 2c: Innovative capability, measured as R&D personnel, negatively moderates the effect of patent expiration on firms' decision to engage in acquisitions.

4.4 DATA AND METHODOLOGY

4.4.1 Dataset

I constructed a panel dataset of 85 horizontal acquisitions among publicly listed US pharmaceutical firms (as defined by firms in SIC 28) during the 1985-2010 period. This data set is tailor-made and draws from several databases. It includes information on all publicly listed U.S. firms involved in acquisitions over the period 1985-2010 where at least one of the acquisition parties is actively involved in innovation activities in the sense that it has applied for at least one patent at the United States Patent and Trademark Office (USPTO) since its foundation. Information about the acquisition deals was extracted from the database Thomson One Banker provided by Thomson Reuters. I consider only those deals that were completed and which involved majority ownership. The acquisition data was linked to firms' financial records which were retrieved from Compustat. The match between the two databases is based on firms' name, state, and the firms' identifiers CUSIP and PERMNO (taken from the Center for Research in Security Prices (CRSP) database).

Information on the patent activity of firms and inventors is taken from the NBER patent database and the Coleman Fung Institute for Engineering Leadership database (Li et al., 2014). Patent information is matched to the firm data using each firm's identifiers and name. The information on publications is extracted from Medline-Science Citation Index (Web of Science) from Thomson Reuters. Pharmaceutical firms' publications were identified on firms' name and firms' address basis, and subsequently manually matched to the information on patents, acquisitions activity, and firms' characteristics. Throughout the whole data linking process, I conducted manual checks, especially for firms for which I discovered missing or ill-defined linkages between the datasets due to misspellings of firm names or identifiers.

4.4.2 Variables

I conceptualized the decision of pharmaceutical firms to undertake an acquisition with a dummy variable that takes the value one when the pharma firm acquires another pharmaceutical firm; i.e., the dependent variable is equal to zero on the years before the acquisition and equal to one thereafter[34].

The main independent variable to explain the decision to buy another firm is patent expiration, measured as the number of patents expiring in the upcoming three years.

The innovative capability is proxied with different dimensions. The first proxy is firms' R&D efforts, measured as the yearly R&D expenditures of the firm (in billions of dollars).

The second proxy, basic research, is measured by the number of firms' scientific publications in Journal Citation Reports (JCR) journals. The number of scientific publications has been shown to reflect the underlying research activity of pharmaceutical firms (Fabrizio, 2009; Gambardella, 1992), particularly of firms' investments in basic science (Cockburn and Henderson, 1998; Gambardella, 1992). Pharmaceutical firms have been found to publish heavily, with a volume comparable to that of similar size institutions or universities (Koening, 1983; Hicks, 1995;

[34] The database construction allows pharmaceutical firms to engage in acquisitions at multiples point in time. For each firm, the dependent variable is zero until it decides to acquire another firm, point at which the dependent variable switches to one to reflect the fact that this firm is now a different entity.

Cockburn and Henderson, 1998). In the pharmaceutical industry, scientific publications legitimate and provide credibility to drugs' efficacy and potential side effects (Kleschick et al., 2001; Balter et al., 2003). Scientific papers influence authorities' drug assessment by reducing the uncertainty that surrounds drugs' unobserved side effects and by favoring FDA approval process (Olson, 1999; Azoulay, 2002; Bodewitz et al., 1987; Pisano, 2006). Scientific publications have the possibility of shorting firms' clinical trial process, speeding up commercialization and increasing the effective patent term. I define the basic research base as the stock of firm's publications. I calculate the publication stock (in hundreds of publications) as follows:

$$\textit{Publication stock}_t = \textit{publication stock}_{t-1}(1-\delta) + \textit{published papers}_t$$

where δ is a constant representing the knowledge depreciation rate that weights the importance of older publications. Following previous patent literature (e.g., Hall, 1990), the depreciation rate, δ, is set equal to 15%.

Finally, I proxy innovative capability with the number of inventors working for the firm. Inventors accumulate both tacit and explicit knowledge that is of particular importance in the context of innovation, as this knowledge is the one underlying firms' inventions (Hoetker and Agarwal, 2007; Nonaka, 1994; Rosen, 1972; Winter, 1987). As is common in the management literature, inventors are identified through patent documents, which contain information about inventors' location and assignees' firm at the time of employment (e.g. Trajtenberg et al., 2006).

Since patent expiration may not be the only reason for engaging in acquisition activities, I control for several firm characteristics that indicate alternative explanations for firms' acquisition decision. Thus, in line with previous studies, I include firms' size, measured as the log of assets, and firms' market capitalization to capture the possibility of firms' merging to achieve economies of scale; to contemplate firms' excessive capacity as a driver of the acquisition decision, I include the percentage change in sales between years t-1 and t-3 and the percentage change in operating expenses between years t-1 and t-3; I also include cash and firms' long term debt (as a ratio to assets) to control for firms' ability to finance the acquisition (Danzon et al., 2007; Higgins and Rodriguez, 2006). Finally, I proxy the ability to generate new innovation output with the number of granted patents applications per year (e.g. Archibugi, 1992; Cohen & Levin, 1989; Griliches, 1990). Further, I use a set of year dummies in order to control for time trends in corporate patenting and acquisitions waves.

4.4.3 Model and estimation technique

To analyze the impact of patent expiration rate on pharmaceutical firms' decision to engage in acquisitions, different specifications are set up. First a basic specification (1), which includes the impact of the factors considered by prior literature (i.e. size of the firm, change in sales, change in operating expenses, market capitalization, cash, and debt) on the likelihood of engaging in acquisitions. Specification (2) includes as well the main explanatory variable of interest, patent expiration. Specifications (3) to (5) build upon specification (2) by including firms' different proxies for innovative capability, each with a different specification to avoid problems of multicollinearity. Since this main interest lies on exploring the impact of patent expiration on firms' acquisition decision, taking into consideration the moderating role of firms' innovative capability, I also include an interaction term between each of the innovative capability proxies and patent expiration. These interaction terms aim to capture the joint effect of firms' innovative capability and patent resources in determining firms' acquisition decision.

The empirical strategy to estimate these equations is based on a panel logit model with fixed effects fitted by maximum likelihood (Wooldridge, 2010). The inclusion of fixed effects allows to control for the unobserved firm characteristics, such as managerial quality, that may affect the acquisition decision. Time dummies are included in all specifications to capture the possible cyclicality in the decision to engage in acquisitions.

I also estimate the marginal effect of patent expiration. However, the estimation of marginal effects using panel logit with fixed effects involves several challenges. Unlike the case of linear models, the marginal effect of an explanatory variable in a non-linear model is not constant over its range (Greene, 2010). This is because calculating the interaction effect requires computing the cross-partial derivative, which is conditional on all the independent variables of the model, so that the marginal effect may actually have different signs for different values of the covariates (Ai and Norton, 2003; Greene, 2010). Unfortunately, without imposing further assumptions, such as the fixed effects are zero, it is impossible to compute the marginal effects for the fixed effects logit model (Ai and Norton, 2003; Karaka-Mandic et al., 2012). Thus, to overcome the problem, I estimate a pooled logit specification with individual dummies and robust standard errors and then compute the marginal effects. Given the large duration of my sample panel (26 years), the incidental parameters problem is almost negligible (Hahn and Newey, 2004), particularly for marginal effects (Fernández-Val, 2009)[35].

In order to show that indeed firms' acquire because they need to replace the expiring patents, I further estimate a fixed effects panel data model in which I include the patents of the target firm[36] as an explanatory variable. I expect that if indeed pharmaceutical firms engage in horizontal acquisitions because their patent portfolio is expiring, they will acquire firms that possess patents that can be exploited by the acquiring firm.

Finally, as robustness checks, I re-estimate the model on a random effects logit set up (see Table A4 in the Appendix) and re-estimate the marginal effects using a panel probit model with individual dummies (see Table A5 and Figure A1 in the Appendix)

4.5 EMPIRICAL RESULTS

4.5.1 Descriptive statistics

Table 4-3 shows the descriptive statistics of the variables of interest.

Pharmaceutical firms have an average of 52 patents expiring in coming three years. Pharmaceutical firms have an average of 5727 millions of dollars in assets. As for the main financial indicators, pharmaceutical sales increase are on average 3918 millions of dollars with operating

[35] The incidental parameters bias is inversely proportional to the panel duration, i.e. it decreases as the time series dimension of the panel increases (e.g. Hahn and Newey, 2004). This explains why, given my sample length, there is little difference between the fixed effects logit specification (which does not suffer from the incidental parameters problem) and the pooled logit specification with individual dummies.
Moreover, several authors have found that marginal effects suffer from the incidental parameters bias to a much lesser extend relative to the coefficient estimates. For example, Fernández-Val (2009) derives theoretical bounds for the incidental parameters bias of marginal effects estimates and shows that it is negligible for various types of unobserved heterogeneity, even when the panel duration is short and shows that the bias can be safely ignored in sufficiently long panels, such as the case of this paper.
[36] Number of the (granted) patent applications of the target in the five years previous to the acquisition (Ahuja and Katila (2001), Cloodt et al. (2006).

expenditures around 2934 million of dollars and a market capitalization of 11,926 million. Cash is on average 397 million and long-term debt represents about 17% of the assets. Pharmaceutical firms expend around 400 million in research and development activities. The pharmaceutical firms of this sample have an average publication stock of 24 publications. Finally, pharmaceutical firms have an average of 73 patent-active inventors.

Table 4-3. Descriptive statistics.

Variable	Mean	Std. dev.	Min.	Max.	Obs.
Patent expiration	52.16	150.70	0	1324	1,372
Log(Assets)	6.31	2.45	0.08	12.27	1,372
Sales	3918.74	9506.36	0	83503	1,372
Operating Exp.	2934.07	7037.51	0.73	63254	1,372
Market Cap.	11.93	30.36	0.00	290.44	1,372
R&D Exp.	0.40	1.05	0	12.18	1,372
Publication stock	0.24	0.65	0	6.14	1,372
Inventors	72.93	195.90	0	16.46.23	1,372
Cash	397.46	10008.67	0	10900	1,372
Long term debt	0.17	0.19	0	2.44	1,372
Patents	29.94	86.44	0	668	1,372

Table 4-4 shows the pairwise correlations between the independent variables. Note that market capitalization, R&D expenditures and publication stock are highly correlated. To tackle the potential problem of multicollinearity, and as mentioned in the previous section, each of the proxies for innovative capability is included in a different specification.

Table 4-4. Correlations.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Patent expiration	1.00							
Log(Assets)	0.51	1.00						
Δ(Sales)	-0.05	-0.12	1.00					
Δ(Operating exp.)	-0.13	-0.18	0.25	1.00				
Market capitalization	0.61	0.59	-0.05	-0.10	1.00			
R&D	0.62	0.56	-0.05	-0.11	0.80	1.00		
Publication stock	0.60	0.53	-0.04	-0.12	0.71	0.85	1.00	
Inventors	0.58	0.48	-0.04	-0.12	0.48	0.41	0.34	1.00

4.5.2 Regression results

Table 4-5 presents the fixed-effects panel logit estimation results. The first column shows the basic specification that includes exclusively the effects of firms' financial characteristics on the probability of pharmaceutical firms to engage in acquisition activities. In line with previous studies, I find that larger firms are more likely to engage in acquisitions. A decrease in operating expenditures increases the likelihood of firms' acquisition decision. Both cash and market capitalization have a positive effect. These coefficients are significant and support previous studies that point towards firms' excess capacity as triggering event of the acquisitions (Danzon et al., 2007). Specification 2 displays the results when the patent expiration is included. I find a significant positive impact of the patent expiration on the likelihood to engage in acquisitions. This is in line with previous management literature that highlight firms' desire to fill up the R&D pipelines as a motive for acquisition (Schweizer, 2005), and with previous financial economics and industrial organization literature that finds a positive effect of patent expiration on acquisition likelihood (Danzon et al., 2007; Higgins and Rodriguez, 2006). Thus, this result supports hypothesis 1.

Table 4-5. FE panel logit for the probability of engaging in acquisitions.

VARIABLES	(1)	(2)	(3)	(4)	(5)
Log(Assets)	3.025***	2.988***	2.786***	2.759***	2.984***
	(0.252)	(0.256)	(0.255)	(0.253)	(0.256)
Δ(Sales)	-0.021	-0.021	-0.019	-0.017	-0.021
	(0.028)	(0.029)	(0.026)	(0.023)	(0.029)
Δ(Operating exp.)	-0.852***	-0.860***	-0.915***	-0.932***	-0.864***
	(0.162)	(0.162)	(0.159)	(0.160)	(0.162)
Mkt. Cap.	0.000**	0.000**	-0.000	0.000***	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Cash	0.002***	0.001***	0.002***	0.001***	0.002***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Long term debt	0.913	0.886	0.877	0.774	0.879
	(0.659)	(0.670)	(0.680)	(0.683)	(0.671)
Patents	0.003	0.000	0.000	0.006	0.001
	(0.003)	(0.004)	(0.005)	(0.006)	(0.007)
Expiring patents		0.015***	0.029***	0.027***	0.017***
		(0.004)	(0.006)	(0.006)	(0.004)
R&D			4.433***		
			(1.177)		
Exp.Patents*R&D			-0.005***		
			(0.001)		
Pub. stock				14.101***	
				(2.833)	
Exp.Pat.*Pub.st				-0.011***	
				(0.003)	
Inventors					0.001
					(0.003)
Exp.Patents*Inv.					-0.000
					(0.000)
Observations	1,372	1,372	1,372	1,372	1,372
Number of firms	82	82	82	82	82
Firm FE	YES	YES	YES	YES	YES
Year Dummies	YES	YES	YES	YES	YES
Log likelihood	-238.565	-227.153	-213.086	-205.302	-226.820
Model chi-square	744.253	767.076	795.210	810.779	767.744
Prob > chi2	0.000	0.000	0.000	0.000	0.000

*Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1*

Specifications 3 to 5, build on specification 2 and include the moderating effect of firms' innovative capability on the decision to engage in acquisitions. In specification 3, I find a significant and negative effect of the interaction of patent expiration and R&D expenditures on the decision to acquire another firm. This means that firms that invest more in R&D activities, when faced with higher patent expiration rates are less likely to engage in acquisitions as compared to firms with lower R&D expenditures. This supports the idea that firms investing in R&D have a higher capacity to generate innovations internally (Hausman et al., 1984), which confers them with a lower reliability on external technology, so that their necessity to acquire other firms to get access to their technology and patent portfolios is lower (Cassiman and Veugelers, 2006; Hagedoorn and Wang, 2012). In specification 4, I find that firms with a larger basic research base are significantly less likely to acquire other firms when faced with higher patent expiration rates. This is consistent with the view that basic research facilitates the research process of firms, pointing them towards new and promising fields (Fleming and Sorenson, 2004), and by increasing the absorptive capacity of external knowledge (Cohen and Levinthal, 1990). This means that firms with a higher basic research base, also have a higher capacity to internally generate new innovations and patents, thus reducing the need to opt for external technology sources when patent expiration rates increase. Finally, in specification 5, while the control and patent expiration variables' coefficient are consistent and significant, the coefficients for inventors and the interaction of inventors with patent expiration yields to non-significant coefficients. Overall, hypotheses 2a and 2b are supported.

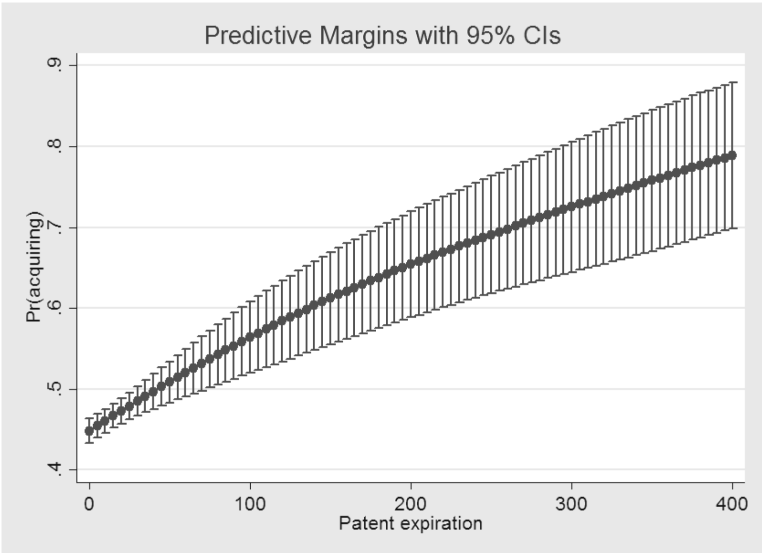
Table 4-6. Pooled logit for the probability of engaging in acquisitions

VARIABLES	(1)	(2)	(3)	(4)	(5)
Log(Assets)	3.517***	3.484***	3.234***	3.207***	3.480***
	(0.637)	(0.653)	(0.642)	(0.628)	(0.652)
Δ(Sales)	-0.024	-0.025	-0.023	-0.021	-0.025
	(0.044)	(0.047)	(0.038)	(0.029)	(0.047)
Δ (Operating exp)	-0.971***	-0.992***	-1.046***	-1.076***	-0.995***
	(0.192)	(0.193)	(0.171)	(0.159)	(0.192)
Mkt. Cap.	0.000**	0.000**	-0.000	0.000***	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Cash	0.002**	0.002*	0.002*	0.002*	0.002*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Long term debt	1.034	1.022	0.969	0.877	1.013
	(0.960)	(0.994)	(1.020)	(1.034)	(0.997)
Patents	0.003	0.001	-0.000	0.007	0.001
	(0.002)	(0.003)	(0.004)	(0.005)	(0.006)
Expiring patents		0.018***	0.035***	0.034***	0.019***
		(0.004)	(0.009)	(0.006)	(0.005)
R&D			5.554***		
			(2.019)		
Exp.Patents*R&D			-0.007***		
			(0.002)		
Pub. stock				17.348***	
				(3.132)	
Exp.Pat.*Pub.st				-0.013***	
				(0.003)	
Inventors					0.001
					(0.003)
Exp.Patents*Inv.					-0.000
					(0.000)
Observations	1,372	1,372	1,372	1,372	1,372
Firm Dummies	YES	YES	YES	YES	YES
Year Dummies	YES	YES	YES	YES	YES
Pseudo Log likelihood	-318.668	-305.525	-288.249	-279.138	-305.168
Pseudo R2	0.664	0.678	0.696	0.706	0.679

*Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1*

The next step in the analysis is to obtain the marginal effects of the patent expiration. Table 4-6 shows the results of the pooled logit with clustered standard errors. The results are consistent with Table 4-5. Figure 4-3 displays the marginal effect of patent expiration. The marginal effects are increasing with the number of patents, meaning that firms with a larger amount of expiring patents have a higher probability of acquiring another pharmaceutical firm. This highlights the idea that firms with more patents expiring will find themselves with larger pipeline and revenues disruptions, so in a greater need for patents (and thus more likely to acquire another firm) to maintain their competitive advantage and revenue streams.

Figure 4-3. Marginal effects for patent expiration.



Finally, specification 3 on Table 4-7, confirms that the targets' firm portfolio explains acquiring firms' decision to engage in acquisitions. In particular, target firms with a higher level of patenting activity on the early stages of their pipeline (i.e. patent applications) increase the probability of the firms' acquisition decisions, supporting the idea that they acquire another firm, among other reasons, because they need to fill their pipeline gaps.

Table 4-7. FE panel logit for the probability of engaging in acquisitions.

VARIABLES	(1)	(2)	(3)
Log(Assets)	3.025***	2.988***	2.482***
	(0.252)	(0.256)	(0.259)
Δ(Sales)	-0.021	-0.021	-0.065
	(0.028)	(0.029)	(0.046)
Δ (Operating exp)	-0.852***	-0.860***	-0.896***
	(0.162)	(0.162)	(0.214)
Mkt. Cap.	0.000**	0.000**	0.000**
	(0.000)	(0.000)	(0.000)
Cash	0.002***	0.001***	0.001**
	(0.000)	(0.000)	(0.000)
Long term debt	0.913	0.886	1.951***
	(0.659)	(0.670)	(0.749)
Patents	0.003	0.000	0.001
	(0.003)	(0.004)	(0.005)
Expiring patents		0.015***	0.021***
		(0.004)	(0.007)
Target patents			0.024**
			(0.010)
Observations	1,372	1,372	1,023
Number of firms	82	82	62
Firm FE	YES	YES	YES
Year Dummies	YES	YES	YES
Log likelihood	-238.565	-227.153	-173.543
Model chi-square	744.253	767.076	571.128
Prob > chi2	0.000	0.000	0.000

*Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1*

4.6 DISCUSSION

The empirical results demonstrate that the loss of competitive advantage derived from the expiration of patents, a key technological asset of pharmaceutical firms, is a mechanism that drives pharmaceutical firms' acquisitions decisions. As highlighted by previous literature, greater levels of patent expiration increase the exposure of pharmaceutical firms to disruptions in their product pipelines and revenues streams and urge them to come up with new patents (Barret et al., 1999; Comanor and Scherer, 2013; Gambardella, 1992; Ravenscraft and Long, 2000). The results suggest that the necessity to replace expiring patents as quickly as possible to minimize the disruptions increases the likelihood of undertaking an acquisition strategy. This is in line with previous literature that highlights the role of external sourcing strategies as an alternative for firms to obtain new technologies and knowledge, especially in the case of pharmaceutical firms where the costs and developing times are high (Cassiman and Veugelers, 2006; DiMasi, 2001; Rigby and Zook, 2002). Moreover, the results confirm previous studies on the preference of firms for different types of external sourcing strategies that emphasize acquisitions as a preferred strategy when the desired technologies and resources at stake are characterized by high levels of uncertainty and tacitness (Folta, 1998; Hagedoorn and Duysters, 2002; Schilling and Steensma, 2002).

The paper also considers the question of whether firms' innovative capability moderates the impact of patent expiration on acquisition decision, or on the contrary, resources alone determine firms' acquisition decision. In particular, three different aspects of innovative capability are examined.

First of all, the results show that firms' R&D internal efforts negatively moderate the impact of patent expiration on the likelihood to engage in acquisitions. R&D efforts, measured as R&D expenditures, has been traditionally linked with a higher capacity to develop innovations internally (DiMasi et al. 1991; Hausman et al., 1984). The negative interaction of patent expiration and R&D efforts found on the empirical results confirm that indeed firms with higher investments in R&D possess a higher capacity to generate new technologies internally, reducing the dependency on external sources of technology development such as acquisitions. This indicates that pharmaceutical firms displaying higher R&D efforts have higher levels of discovery and clinical development activities, which translate into a higher number potential drug candidates and (patentable) molecules.

Secondly, the results also support the negative moderating effect of basic research. As with R&D efforts, higher levels of basic research correspond to higher levels of activity particularly in the early stages of the drug discovery process (Gambardella, 1992; Hicks, 1995). The results suggest that firms that have strong basic research base, i.e. research activities oriented towards the understanding of diseases and creating new molecules, possess the raw material necessary to come up in-house with new drugs and patents. Thus, even if a number of expiring patents increases, firms with high levels of basic research always have some molecules and compounds in their pipeline that can be further developed into drugs and be exploited in the form of patents, reducing their necessity of obtaining these new technologies and knowledge from outside the firm.

These results found for R&D efforts and basic research are in line with the core of the knowledge-based view literature that emphasizes the importance of internal research capabilities and basic research as engines that fuel the process of innovations generation (Liberman, 1987) by providing a knowledge foundation which firms can draw from when conducting technological activities and developing new inventions (Arora and Gambardella, 1994; Klevorick et al., 1995; Nelson, 1962; Rosenberg, 1990).

Finally, our results do not find support for a moderation effect of the number of inventors. This is surprising given that the pattern of employment of scientists and inventors in the pharmaceutical industry parallels R&D expenditures (Cohen, 2005) so that we would expect a significant negative effect on the interaction effect. This inconsistency may be rooted in the way the R&D personnel is measured. R&D personnel only records those inventors that appear as inventors in pharmaceutical firms' patent applications documents, which may not reflect firms' entire R&D human assets. On the one hand, patent applications may only show the head of the departments and not complete research teams. On the other hand, granted patent applications only show those inventors that are able to patent successfully, only reflecting the output of crucial inventors and possibly ignoring non-successful scientists that are also part of pharmaceutical firms' R&D scientific teams.

4.7 CONCLUSION

Despite the topic of technologically related acquisitions has been exhaustively studied by previous management and economics literature (see Veugelers, 2006, for a survey), these studies have mainly focused on the post-acquisition performance of firms (e.g. Ahuja and Katila, 2001; Cassiman et al., 2005; Cloodt et al., 2006; King et al., 2004), devoting very little attention to the reasons behind firms' decisions to engage in acquisition activities (Andrade et al., 2001; Higgins and Rodriguez, 2006). Framed in the RBV literature, this paper aims at filling this gap by studying the impact of patent expiration on pharmaceutical firms' likelihood of undertaking an acquisition strategy, taking into consideration the moderating role played by firms' innovative capability. The results show that indeed patent expiration is a triggering factor of firms' acquisition decision, which is explained by the short-term necessity of firms to fill the pipeline gaps left by expiring patents and to maintain revenue streams. This effect is moderated by firms' innovative capability. In particular, for firms with a stronger basic research base or with higher R&D efforts the effect of patent expiration on the acquisition decision is not as pronounced. This is because R&D and basic research base facilitate firms' research process, providing them with a higher capability to internally generate new innovations, thus reducing the external dependency.

This study contributes to the current literature in several ways. First, it adds to the RBV by highlighting a mechanism through which firms' resources affect firms' strategic decisions. Previous RBV literature has remained silent regarding the motives behind firms' acquisitions decisions. In this paper, I provide an explanation of why firms, in the event of a loss of the competitive advantage provided by patents, which represent a key resource, may choose to engage in an acquisition strategy to re-fill their patent portfolio. Secondly, I present a link between resources and capabilities, and strategy that leads to important insights into firms' innovation management and highlights acquisitions as an important means of innovation management. On the empirical results section, I show that the decision to engage in acquisitions is not alone determined by resources, but also by the firms' capabilities, as seen by the significance of the interaction effects. Third, I stress the importance of innovation indicators as anticipating factors of acquisition activity. For its vast majority, indicators used in the literature to monitor firms' decision to engage in acquisitions are based on firms' financial indicators (e.g. market capitalization, ratio cash to sales, Tobin's q) or on trends (e.g. industry trends or acquisitions waves). As compared to the current indicators, patent expiration does not rely on the financial situation of the firm but rather on the innovation portfolio of the firm. This is particularly interesting from the empirical point of view as the use of patent expiration is less problematic in terms of causality and endogeneity. This is because patent expiration is exogenous to the firm since patents' life duration is externally fixed by the USPTO; exogeneity, however, cannot be ensured with financial indicators as changes in firms' financial statements may be a response to firms' acquisition decision, through for example a managerial change in strategy or as a consequence of markets' rumors about the acquisition.

This study suggests that managers should pay attention to and plan for long-term innovation strategies. The results show that a clever patent portfolio management and strategic timing of patent applications as well as strong internal research capabilities can avoid depletion on firms' patent portfolio and the associated disruptions in the pharmaceutical pipelines.

As any, this study is not free of limitations. First of all, these results refer to the pharmaceutical industry, and thus, cannot be translated to low innovative industries or industries in which trade secrecy is the major strategy to protect innovation breakthroughs. Secondly, this paper focuses acquisitions of new patents through acquisitions, ignoring other mechanisms such as patents' rights transfers[37] or patent licensing. Thus, it may be interesting to complement the current study with patent transfer and patent licensing data. For future research, it would also be interesting to investigate how much does patent expirations weight in the decision to

[37] The USPTO Patent Assignment Dataset collects information on patents' transfers (either individually or in a bundle). These dataset however suffer from several limitations that complicates the analysis: (1) names of buyers and sellers are not standardized on the dataset, which makes tracking a very difficult task; (2) the database doesn't allow to distinguish between patents acquired to be exploited or patents acquired to be licensed out (Serrano, 2010). Moreover, in his study of patent transfer, Serrano (2010) indicates that for the drugs and medical industry, patent transfer represents only about 16%. He also recognizes that this dataset, however doesn't distinguish between the acquisition of a bundle of patents from the acquisition of a firm, meaning that there are large amounts of overlapping between the USPTO Patent Assignment Dataset and the acquisition dataset.

engage in acquisitions as compared to other factors such as financial performance or assets of the target and acquiring the firm.

CHAPTER 5

CONCLUSION

5.1 OVERVIEW OF MAIN FINDINGS AND IMPLICATIONS

The main objective of this dissertation is to develop a better understanding of the interrelation of M&As and innovation, with a particular focus on the innovation antecedents of M&As and on the consequences of M&As on innovation. With this purpose, each of the chapters in this dissertation reviewed the relevant literature, identified the research gap in the existing literature, posed a research question and empirically examined it. In the next section, an overview of the main findings and implications of each of the papers is presented.

5.1.1 Hiring New Key Inventors to Improve Post-M&A Innovation Performance

The main objective of Chapter 2 is to provide some measures to counteract the innovation performance declines observed in the post-M&A period. The paper first disentangles the different channels for the decline in post-M&A innovation performance, distinguishing between innovation performance declines due to inventor departure and innovation performance decreases of incumbent inventors that stay with the merged entity. The paper finds that the effect on innovation performance of the inventors that stay within the firm is larger than the well-researched effect of inventor departure. Building on this finding, the paper proposes a counteracting measure that acquiring firms can take to remedy the post-M&A innovation declines. The main two hypotheses (hypotheses 4 and 5) from the paper explore the impact of this counteracting measure on acquiring firms' innovation:

Hypothesis: Newly hired key inventors are positively associated with the acquiring firm's post-M&A innovation performance (direct effect).
Hypothesis: Newly hired key inventors are positively associated with the contribution of incumbent inventors to the acquiring firm's post-M&A innovation performance (indirect effect).

The empirical analysis confirms the hiring of key inventors as a measure to enhance firms' innovation performance after an M&A. First, the newly hired key inventors provide the acquiring firm with new skills, competencies, and experience (Rao and Drazin, 2002) gathered at their former employer (Barney, 1991; Groysberg et al., 2008) that increase innovation performance of the acquiring firm by increasing its knowledge base. Second, newly hired key inventors improve the productivity of the inventors already working for the acquiring firm. Hiring new key inventors sends a positive signal to incumbent inventors, reassuring that innovation is of importance to the firm, even in times of corporate restructuring. As inventors have a strong preference to work with higher qualified colleagues

(Barabasi et al., 2002; Wagner and Leydesdorff, 2005), newly hired key inventors can also increase the motivation and productivity of incumbent inventors (Allison and Long, 1990).

The paper contributes to the literature on M&As in two different ways. Firstly, it adds to the prior literature on inventor behavior around M&As (Ernst and Vitt, 2000; Kapoor and Lim, 2007; Paruchuri et al., 2006) by disentangling different channels for the decline in post-M&A innovation performance. The paper further finds that the effect on innovation performance of the inventors that stay within the firm is larger than the well-researched effect of inventor departure, which is an interesting finding given that prior literature pays a lot of attention to the consequences of inventor departure after M&As (Ernst & Vitt, 2000; Kapoor and Lim, 2007; Larsson and Finkelstein, 1999; Paruchuri et al., 2006). Secondly, the paper demonstrates that the hiring of key inventors has important direct and indirect effects on post-M&A innovation performance where the latter effect refers to a positive effect of new key inventors on incumbent inventors' contribution to the firm's innovation performance.

These results indicate that an appropriate human capital strategy around the M&A event can help avoiding a temporary decrease in innovation performance in the post-M&A period. The findings have important practical implications for executives being involved in an M&A, suggesting a proactive human resource strategy, avoiding a brain drain and stimulating the hiring of external key inventors. More importantly, the paper indicates that managerial attention during the M&A period should focus rather on the inventors that stay with the firm than on the inventors that are departing. This can be seen as good news for managers because it is relatively easier to foster and support the innovation activities of inventors that stay than to design attractive contracts for those inventors that are planning to leave the firm. In fact, appropriate internal policies to foster innovation can also stop inventors from departing (Groysberg and Lee, 2010).

5.1.2 Knowledge Diffusion through M&As

The main goal of Chapter 3 is to explore the role of M&As as a channel of knowledge diffusion. In particular, it takes a policy perspective to examine whether the observed inventor departure around the M&A period represents a mechanism by which knowledge diffuses within and across industries. The paper takes as departure point U.S. competition authorities' regulations, which recognize M&As as a potentially anticompetitive mechanism affecting innovation, and inventor mobility literature, which claims mobility as a channel for knowledge diffusion, to profile inventors and firms to determine the extent to which M&As facilitate knowledge diffusion.

The paper shows that M&As are not able to capture the complete technical knowledge of both merging parties. The paper finds that about a 4% of the inventive labor force leaves around the M&A event to firms with similar characteristics as the M&A firms; 63% of the inventors to firms within the same industry and 76% to firms with a similar technological profile as the former M&A employer. The results also show that inventors' experience and patent productivity reduces the probability of moving to firms with a lower technological profile, while non-compete agreements trigger the mobility of firms with a lower technological profile.

This study is relevant from the policy point of view as current regulations mainly consider the potential effects that M&A-induced changes in the innovation activities of the merged entities, overlooking possible diffusion effects that M&As may have on the innovation activities of third non-merging parties (Haucap and Stiebale, 2016). In particular, in light of current regulations (2010 U.S. Horizontal Merger Guidelines), which impose divestitures as a relief for innovation anti-competitive effects, this paper points to a knowledge re-distribution mechanism that takes place without the intervention of competition authorities.

The results presented in Chapter 3, highlight the necessity of firms to manage inventor departure and disappearance around the M&A event. As Chapter 3 shows, there is a large proportion of inventors that disappear or leave the firm, not patenting anymore for either the target or the acquiring firm. While in Chapter 3, we point towards a possible re-distribution of knowledge from M&A firms to non-M&A firms, with the associated positive consequences for the overall economic system, this redistribution of knowledge has undoubtedly negative consequences for the M&A firms. The analysis conducted in Chapter 2 (hypothesis 2) provided evidence of the negative impact of the disappearance/mobility on M&A firms' innovation performance.

5.1.3 Patent expiration as an acquisition motive in the pharmaceutical industry

Chapter 4 seeks to provide empirical evidence that innovation is a driving factor in pharmaceuticals firms' decisions to engage in horizontal acquisitions. The paper focuses on patent expiration as innovation mechanism that motivates firms' decision to engage in acquisition activities. The paper, which is framed in the RBV literature, explores whether loss of strategically key innovation resources pushes firms to undertake acquisition activities, considering as well the moderating role that firms' innovative capability plays in this decision. Thus, the main hypothesis (hypothesis 1) of the paper is as follows:

Hypothesis: Patent expiration positively influences firms' decisions to engage in horizontal acquisitions.

The results show that indeed patent expiration is a triggering factor in firms' acquisition decision. This suggests that pharmaceutical firms resort to acquisitions when they need to fill the pipeline gaps left by expiring patents and to maintain revenue streams. The empirical results also show that innovative capability negatively moderates this effect. In particular, the results show that for pharmaceutical firms that possess a large basic research base and that have higher levels of R&D efforts, the effect of patent expiration on the decision to engage in acquisitions is not as pronounced. This indicates that firms with higher R&D and basic research, which facilitate firms' research process, build a higher capacity to internally generate new innovations, reducing their external dependency.

This study contributes to the current literature in several ways. First, it contributes to the RBV literature by highlighting a mechanism through which firms' resources affect firms' strategic decisions. Previous RBV literature has remained silent regarding the motives behind firms' acquisitions decisions. Second, the paper presents a link between resources and capabilities and strategy that leads to important insights into firms' innovation management and points to acquisitions as an important means of innovation management. Finally, the paper stresses the importance of innovation indicators as anticipating factors of acquisition activity. In particular, from the empirical point of view, patent expiration, as compared to the traditionally used financial indicators, has the advantage of being less problematic in terms of causality and endogeneity since patents' life duration is externally fixed by the USPTO.

This last chapter suggests that managers should pay attention to and plan for long-term innovation strategies. The results show that a clever patent portfolio management and strategic timing of patent applications as well as strong internal research capabilities can avoid depletion on firms' patent portfolio and the associated disruptions in the pharmaceutical pipelines.

5.2 LIMITATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

The papers presented in this dissertation are subject to some common limitations derived from, among others, the data set, and the definitions of key concepts such as innovation or mobility.

First of all, as with other studies in the inventor mobility literature (e.g. Almeida and Kogut, 1999; Ge et al., 2016; Hoisl, 2007; Li et al., 2014; Singh and Agrawal, 2011; Trajtenberg, et al., 2006), this dissertation defines mobility based on patent documents. This means that mobility can only be identified when the inventor has at least successfully patented twice, both before and after moving, and when inventor's employer chooses to patent over secrecy (Cohen et al., 2000; Png, 2015). A further complication of this patent-based definition is that it is not possible to observe the reasons for inventors' departure or to distinguish between voluntary and involuntary departure. Alternative definitions of mobility, based for example in LinkedIn profiles (Ge et al., 2016), would be a very interesting robustness check, provided that sufficient and non-biased profiles are available as well as a sufficient overlap with existing databases.

Second, patent counts are an imperfect measure of a firm's innovative output. Patents represent only a portion of firms' innovative activity and output, with the ratio of patented inventions varying considerably across industries (Hall et al., 1996). Moreover, while existing other alternatives, such as secrecy, to protect inventions, many inventions are not patented for strategic reasons (Griliches, 1990). In this case, industry-specific studies might mitigate these concerns by reflecting the inherent characteristics of the industry in terms of patentability and facilitating the comparison across firms.

In this sense, for the last study, in Chapter 4, focusing on a single industry, the pharmaceutical sector, minimizes the concerns related to inter-industry variation and facilitates the explanation of the different mechanisms, but at the same time limits the generalizability of results to other industries. Moreover, given the unique characteristics of the pharmaceutical industry in terms of patentability, the results can be hardly translated to low innovative industries or industries in which trade secrecy is the major strategy to protect inventions. An interesting exercise for the future could be to expand the study to include other high-tech industries with both high and low patentability to get a deeper understanding of the role of patents and innovation in M&As.

Finally, regarding the possible concerns with endogeneity and causality, M&As are a very complex phenomenon that occurs in an endogenous system of strategic choices, in which, unfortunately, is not possible to observe all the reasons and strategic decisions behind the M&As. This limitation, which is very much present in every quantitate empirical study, might mean that the models presented here may not capture the complete reality of M&As, potentially producing biased results. While permitting the generalization of findings, large-scale studies, such as the ones presented in this dissertation, lack the ability to grasp and capture all the aspects of each individual M&A. Thus, for future research, it would be interesting to complement our large sample findings with in-depth case study evidence, which allows for a deeper investigation.

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APPENDICES

Table A1. Bivariate correlations.

Variable	(1)	(2)	(3)	(4)	(5)
Patents per year	1				
ASSETS	0.25*	1			
INVENTORS	0.06*	-0.29*	1		
DEPARTING	0.09*	0.09*	0.20*	1	
After M&A	0.00	0.22*	-0.15*	0.08*	1
KEY	-0.01	-0.04*	0.16*	0.18*	-0.07*

*Note: *p<0.05, **p<0.01, *** p<0.001*

Table A2. Estimation results for the probability of moving to a firm in the same technological leadership group (Three-stage Heckman selection model).

	(A)			(B)		
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Same Tech Leadership	Departure	Non-disappear	Same Tech Leadership	Departure	Non-disappear
Experience	0.144*	0.087***	0.203***	0.137	0.076**	0.203***
	(0.076)	(0.029)	(0.003)	(0.086)	(0.030)	(0.003)
(Exp)^2	-0.006*	-0.004***	-0.007***	-0.006	-0.003***	-0.007***
	(0.003)	(0.001)	(0.000)	(0.004)	(0.001)	(0.000)
Patents/Exp	0.473***	0.217***	0.254***	0.473***	0.206***	0.255***
	(0.107)	(0.035)	(0.015)	(0.125)	(0.037)	(0.015)
(Pat./Exp)^2	-0.012**	-0.005***	0.002	-0.012**	-0.005***	0.002
	(0.005)	(0.001)	(0.003)	(0.006)	(0.001)	(0.003)
Cit./Patents	-0.017	0.016***	0.008***	-0.018	0.015**	0.008***
	(0.023)	(0.006)	(0.002)	(0.023)	(0.006)	(0.002)
(Cit./Pat.)^2	-0.000	-0.000*	-0.000***	-0.000	-0.000	-0.000***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Ind. non-compete	-0.016	-0.008	-0.048***	-0.089	0.008	-0.051***
	(0.171)	(0.057)	(0.014)	(0.188)	(0.059)	(0.014)
High tech				-0.138	0.108**	0.019
				(0.153)	(0.045)	(0.014)
Medium-high tech				0.109	0.134***	0.003
				(0.161)	(0.049)	(0.014)
Medium-low tech				0.082	-0.169*	0.134***
				(0.272)	(0.098)	(0.028)
Number of names			0.064***			0.063***
			(0.010)			(0.010)
Leaving inventors %		2.787***			2.837***	
		(0.283)			(0.261)	
Observations	809	18,184	66,671	809	18,184	66,671
Year dummies	YES	YES	YES	YES	YES	YES
Log likelihood	-40021.178	-40021.178	-40021.178	-39995.590	-39995.590	-39995.590
Model chi-square	12563.608	12563.608	12563.608	12614.784	12614.784	12614.784
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000
Rho	0.349^{α}	0.307^{β}	-0.0904^{γ}	0.231^{α}	0.180^{β}	0.039^{γ}
LR test of indep.	0.293	0.700	0.648	0.405	0.814	0.800

*Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1*
α: rho of 2nd with 3rd stage; β: rho of 1st with 3rd stage; γ rho of 1st with 2nd stage.

Table A3. Estimation results for independent probits.

VARIABLES	(1) Non-disappear	(2) Departure	(3) Same industry	(4) Lower Tech Leadership	(5) Same Tech Leadership
Experience	0.203***	0.050***	0.035	-0.113***	0.117***
	(0.003)	(0.012)	(0.037)	(0.041)	(0.041)
(Exp)^2	-0.007***	-0.002***	-0.002	0.005**	-0.005**
	(0.000)	(0.001)	(0.002)	(0.002)	(0.002)
Patents/Exp	0.257***	0.174***	-0.025	-0.450***	0.448***
	(0.015)	(0.019)	(0.067)	(0.097)	(0.096)
(Patents/Exp)^2	0.001	-0.004***	-0.002	0.011**	-0.011**
	(0.003)	(0.001)	(0.005)	(0.005)	(0.005)
Citations/Patents	0.008***	0.014**	-0.013	0.019	-0.019
	(0.002)	(0.006)	(0.037)	(0.023)	(0.023)
(Cit./Patents)^2	-0.000***	-0.000	-0.002	0.000	-0.000
	(0.000)	(0.000)	(0.002)	(0.001)	(0.001)
Ind. non-compete	-0.050***	0.015	0.028	0.087	-0.087
	(0.014)	(0.060)	(0.162)	(0.188)	(0.188)
High tech	0.019	0.108**	0.695***	0.142	-0.141
	(0.014)	(0.046)	(0.134)	(0.153)	(0.153)
Medium-high tech	0.003	0.138***	0.175	-0.117	0.111
	(0.014)	(0.049)	(0.155)	(0.162)	(0.162)
Medium-low tech	0.134***	-0.188**	-0.619**	-0.075	0.079
	(0.028)	(0.096)	(0.259)	(0.260)	(0.260)
Number of names	0.064***				
	(0.010)				
Leaving inventors %		2.884***			
		(0.244)			
Observations	66,671	18,184	809	842	842
Year dummies	YES	YES	YES	YES	YES
Log likelihood	-37031.433	-2634.359	-403.819	-330.098	-330.197
Model chi-square	11440.407	923.420	226.800	253.563	255.745
Prob > chi2	0.000	0.000	0.000	0.000	0.000
Pseudo R2	0.134	0.149	0.219	0.277	0.279

*Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1*

Table A4. RE panel logit for the probability of engaging in acquisitions.

VARIABLES	(1)	(2)	(3)	(4)	(5)
Log(Assets)	2.643***	2.686***	2.649***	2.677***	2.681***
	(0.240)	(0.243)	(0.244)	(0.247)	(0.243)
Δ(Sales)	-0.024	-0.026	-0.025	-0.025	-0.025
	(0.026)	(0.027)	(0.027)	(0.027)	(0.027)
Δ (Operating exp)	-0.762***	-0.781***	-0.797***	-0.775***	-0.780***
	(0.154)	(0.157)	(0.160)	(0.158)	(0.157)
Mkt. Cap.	0.000	0.000	-0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Cash	0.001***	0.001***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Long term debt	0.998	0.999	0.995	0.966	0.999
	(0.615)	(0.624)	(0.634)	(0.631)	(0.623)
Patents	0.001	-0.001	-0.002	-0.001	-0.002
	(0.002)	(0.003)	(0.003)	(0.003)	(0.006)
Expiring patents		0.008***	0.014***	0.012***	0.007**
		(0.002)	(0.004)	(0.003)	(0.003)
R&D			2.341***		
			(0.746)		
Exp.Patents*R&D			-0.003***		
			(0.001)		
Pub. stock				2.875***	
				(1.041)	
Exp.Patents*Pub.st				-0.006***	
				(0.002)	
Inventors					-0.000
					(0.003)
Exp.Patents*Inv.					0.000
					(0.000)
Observations	1,372	1,372	1,372	1,372	1,372
Number of firms	82	82	82	82	82
Firm RE	YES	YES	YES	YES	YES
Year Dummies	YES	YES	YES	YES	YES
Log likelihood	-548.726	-540.989	-532.677	-534.833	-540.881
Model chi-square	163.105	163.533	163.236	163.831	163.222
Prob > chi2	0.000	0.000	0.000	0.000	0.000

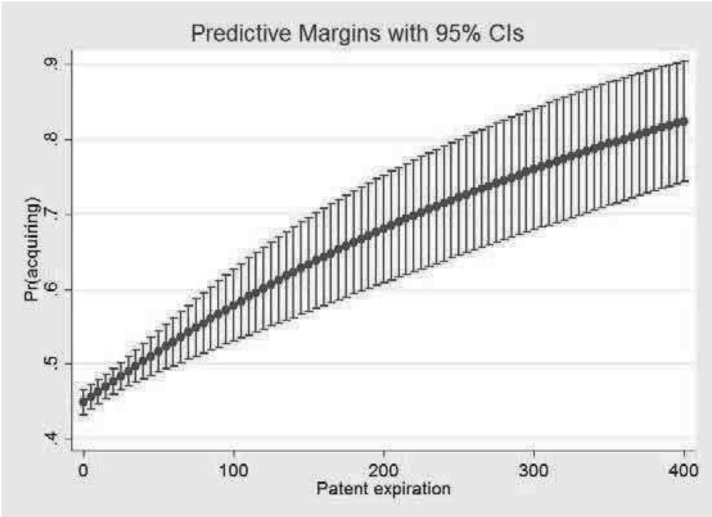
*Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1*

Table A5. Pooled probit for the probability of engaging in acquisitions.

VARIABLES	(1)	(2)	(3)	(4)	(5)
Log(Assets)	1.511***	1.515***	1.442***	1.403***	1.514***
	(0.197)	(0.198)	(0.195)	(0.194)	(0.197)
Δ(Sales)	-0.012	-0.013	-0.012	-0.011	-0.013
	(0.015)	(0.017)	(0.015)	(0.013)	(0.017)
Δ (Operating exp)	-0.509***	-0.521***	-0.548***	-0.568***	-0.522***
	(0.091)	(0.092)	(0.086)	(0.083)	(0.091)
Mkt. Cap.	0.000***	0.000**	-0.000	0.000***	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Cash	0.001***	0.001***	0.001**	0.001**	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Long term debt	0.507	0.507	0.486	0.448	0.503
	(0.375)	(0.384)	(0.392)	(0.396)	(0.386)
Patents	0.002	0.000	-0.000	0.004	-0.000
	(0.001)	(0.002)	(0.002)	(0.003)	(0.004)
Expiring patents		0.010***	0.020***	0.019***	0.011***
		(0.002)	(0.003)	(0.003)	(0.002)
R&D			3.111***		
			(0.716)		
Exp.Patents*R&D			-0.004***		
			(0.001)		
Pub. stock				9.661***	
				(1.571)	
Exp.Patents*Pub.st				-0.007***	
				(0.001)	
Inventors					0.001
					(0.002)
Exp.Patents*Inv.					-0.000
					(0.000)
Observations	1,372	1,372	1,372	1,372	1,372
Firm Dummies	YES	YES	YES	YES	YES
Year Dummies	YES	YES	YES	YES	YES
Pseudo Log likelihood	-337.722	-323.019	-302.776	-294.054	-322.522
Pseudo R2	0.644	0.660	0.681	0.690	0.660

*Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1*

Figure A1. Marginal effects for patent expiration.



VALORIZATION

In this addendum, I outline the valorization opportunities for the empirical studies presented in this dissertation, including the managerial and economic relevance of the research topics, the innovativeness of the research findings, and their value for firm innovation and practices in management.

As explained in the introductory chapter, the main purpose of this dissertation is to develop a better understanding of the inter-relation between M&As and innovation, paying a particular attention to the antecedents and consequences of M&As. On the one hand, innovation has increasingly become an important way for firms to obtain and maintain a competitive advantage and to achieve a higher performance in the long run (Cassiman and Colombo, 2006; Conner, 1991; Hitt et al., 1997; Teece et al., 1997). On the other hand, M&As have become a popular strategy to access new knowledge, capabilities and technology assets, and know-how held by the acquisition target (Arora, Fosfuri & Gambardella, 2001; Capron, Dussauge & Mitchell, 1998; Cassiman, Colombo, Garrone &

Veugelers, 2005; Granstrand & Sjolander, 1990; Graebner, 2004). Nevertheless, despite the potential benefits M&As provide access to, a set of mixed innovation and performance results have been found. M&As studies report both positive and negative effects, but with a large body of literature documenting a negative impact of M&As on corporate innovation (e.g. Cassiman et al., 2005; Prichett, 1985; Ravenscraft and Scherer, 1987; see Veugelers, 2006, for a survey of the literature). These fragmented findings suggest that M&As are still not very well understood and that scholars still know very little about what makes M&As succeed or fail (Bower, 2001; Hoskisson et al., 1991; Jemison and Sitkin, 1986; Schweizer, 2005). Trying to add to this discussion, three research questions have been explored in this dissertation.

The first empirical study in this dissertation explores a mechanism by which firms can counteract the post-M&A negative effects on innovation. This study makes use of the literature that illustrates the importance of the transferability of knowledge across and within firms through individual talents (Kim, 1997; Song et al., 2003; Zander and Kogut, 1995) to explore the potential role that key inventors play in knowledge transfer in periods of reorganization and that can mitigate negative innovation performance effects in post-M&A periods. Previous literature has highlighted that changes in aftermath of M&As disrupt firms' routines in the post-M&A period creating uncertainty that generates demotivation and cognitive barriers to knowledge exploitation (Jensen & Szulanski, 2004; Minbaeva, Pedersen, Björkman, Fey & Park, 2003). These studies have indicated that inventors react with departure or decreasing innovation performance (Ernst & Vitt, 2000; Kapoor & Lim, 2007; Paruchuri et al., 2006).

The results from the empirical analysis confirm the hiring of key inventors as a measure to enhance firms' innovation performance after an M&A. On the one hand, newly hired key inventors provide the acquiring firm with new skills, competencies, and experience gathered at their former employer that increase innovation performance of the acquiring firm by increasing its knowledge base (Barney, 1991; Groysberg et al., 2008). On the other hand, these newly hired key inventors improve the productivity of their new co-workers. Hiring new key inventors sends a positive signal to incumbent inventors, reassuring that innovation is of importance to the firm, even in times of corporate restructuring. Moreover, as inventors have a strong preference to work with higher qualified colleagues (Barabasi et al., 2002; Wagner and Leydesdorff, 2005), newly hired key inventors can also increase the motivation and productivity of incumbent inventors

(Allison and Long, 1990). From a managerial perspective, these results indicate that an appropriate human capital strategy around the M&A event can help avoiding a temporary decrease in innovation performance in the post-M&A period. The findings have important practical implications for executives being involved in an M&A, suggesting a proactive human resource strategy, avoiding a brain drain and stimulating the hiring of external key inventors. More importantly, the paper indicates that managerial attention during the M&A period should focus rather on the inventors that stay with the firm than on the inventors that are departing. This can be seen as good news for managers because it is relatively easier to foster and support the innovation activities of inventors that stay than to design attractive contracts for those inventors that are planning to leave the firm.

The second study takes a policy perspective on the topic of M&As and innovation and explores the potential of M&As as channels for knowledge dissemination. As explored on the first study of this dissertation, a major obstacle to realize innovation gains after M&As is the departure of the inventive labor force (Ernst and Vitt, 2000; Paruchuri et al., 2006; Kapoor and Lim, 2007). Taking the findings from the first as departure point, the paper empirically examines the patterns of mobility of inventors during the post-M&A period to determine whether and to which extent M&As represent a mechanism of knowledge diffusion through mobile inventors (Kogut and Zander, 1992; Schumpeter, 1934). While previous literature only acknowledges the negative effects of inventors' departure in the merging firms' innovation, this study goes beyond to explore the potential positive effects derived from the post-M&A departure of inventors on third (non-M&A) parties.

The analysis from this paper shows that M&As are not able to capture the complete technical knowledge of both merging parties. The paper finds that about a 4% of the inventive labor force leaves around the M&A event to firms with similar characteristics as the M&A firms. This study is relevant from the policy point of view as current regulations mainly consider the potential effects that M&A-induced changes in the innovation activities of the merged entities, overlooking possible diffusion effects that M&As may have on the innovation activities of third non-merging parties (Haucap and Stiebale, 2016).

Finally, the fourth chapter of this dissertation examines an innovation mechanism that motivates pharmaceutical firms' decision to engage in M&As. In particular, this paper studies the impact that the expiration of patents, as a technological source of competitive advantage, has on firms' decision to engage in acquisition activities. Previous literature has pointed the need for an adequate empirical research on acquisitions that deepens on the motives, industry sector and firm characteristics to understand the performance outcomes of acquisitions and the high failure rates (Bower, 2001; Pablo and Javidan, 2004; Schweizer, 2005; Sirower, 1997).

The empirical analysis from this study suggests that patent expiration is a triggering factor in firms' acquisition decision. This indicates that pharmaceutical firms resort to acquisitions when they need to fill the pipeline gaps left by expiring patents and to maintain revenue streams. The empirical results also show that innovative capability negatively moderates this effect. In particular, for pharmaceutical firms that possess a large basic research base and that have higher levels of R&D efforts, the effect of patent expiration on the decision to engage in acquisitions is not as pronounced. From a managerial point of view, the paper stresses the importance of innovation indicators as anticipating factors of acquisition activity. Moreover, this last chapter suggests that managers should pay attention to and plan for long-term innovation strategies. A clever patent portfolio management and strategic timing of patent applications, as well as strong internal research capabilities, can avoid depletion on firms' patent portfolio and the associated disruptions in the pharmaceutical pipelines.

Overall, the studies presented in this dissertation as particularly useful for managers and policy makers, especially those dealing with innovation intensive industries or firms. As mentioned above, in the recent decades, firms' competitiveness has increasingly become dependent on its ability to keep up with innovative products and processes, and R&D activities, which stimulate innovation and improve firms' absorptive capacity. R&D activities lead to the creation of new technologies that can be used to develop new products that satisfy consumers' needs and market demand, or to develop new processes that lower the production costs, increasing market share, sales and profits. However, while firms' main innovation input comes from internal R&D activities, the increasing complexity of research, as well as the fast pace of technological change, technological and non-technological firms, rely on knowledge external to the firm obtained, among others, through M&As. The increasing importance of M&As has been reflected in the number and value of M&As transactions in the last couple of years with over 13,000 transactions representing over $1.700 trillion in 2016 (S&P Global Market Intelligence, 2017). Thus research on the relation of M&As and innovation represents an important venue for managers and policy makers to understand the factors that affect performance outcomes of acquisitions and the high failure rates. I hope that the studies presented in this dissertation shed some light in this direction.

BIOGRAPHY

Marta Fernández de Arroyabe Arranz was born on December 28th, 1989 in Madrid (Spain). She obtained her Master's degree in Economics and Financial Research at Maastricht University (the Netherlands) in 2014. In September 2014 she joined the Centre for Research in Economics and Management (CREA) at University of Luxembourg as a Ph.D. candidate under the supervision of Prof. Dr. Katrin Hussinger and Prof. Dr. John Hagedoorn (UNU-Merit). Her thesis was written under the jointly supervised double degree program of the University of Luxembourg and Maastricht University.

Since January 2018, Marta is lecturer at Essex Business School (University of Essex). Her work has been published in the *British Journal of Management*, *Technological Forecasting and Social Change*, and *Studies in Higher Education*.

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